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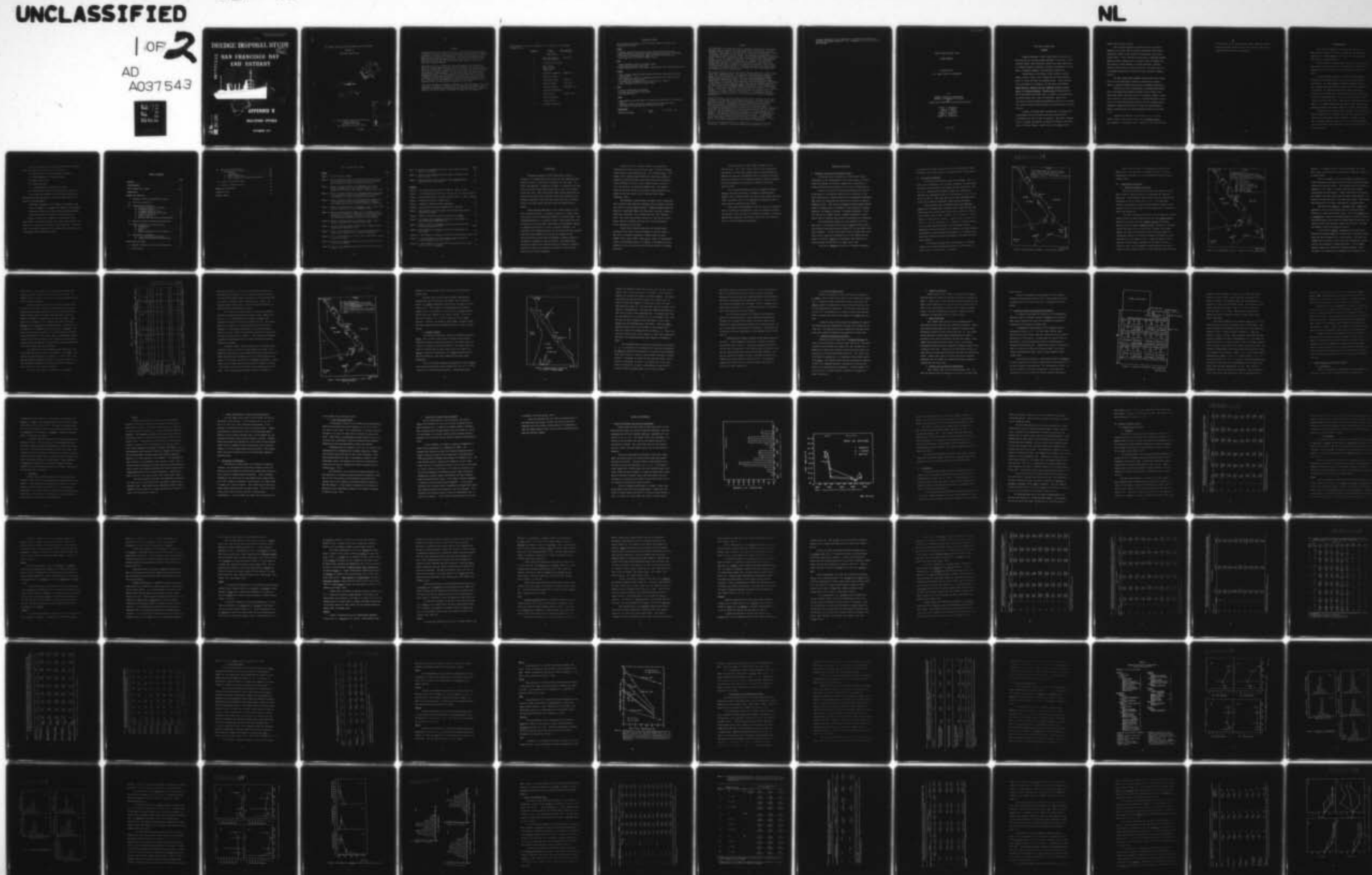

DREDGE DISPOSAL STUDY

SAN FRANCISCO BAY AND ESTUARY

APPENDIX H

POLLUTANT UPTAKE

SEPTEMBER 1975

(6) DREDGE DISPOSAL STUDY SAN FRANCISCO BAY AND ESTUARY

APPENDIX H

POLLUTANT UPTAKE STUDY

(11) Sept~~ember~~ 1975

(12) 169p.

U.S. Army Engineer District, San Francisco
Corps of Engineers
100 McAllister Street
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FOREWARD

In April 1972, the San Francisco District of the United States Army Corps of Engineers initiated a three and one-half year $3 million study to quantify the impact of dredging and dredged material disposal operations on the San Francisco Bay and Estuarine environment. The study is generating factual data, based on field and laboratory studies needed for the Federal, State and local regulatory agencies to evaluate present dredging policies and alternative disposal methods.

The study is set up to isolate the questions regarding the environmental impact of dredging operations and to provide answers at the earliest date. The study is organized to investigate (a) the factors associated with dredging and the present system of aquatic disposal in the Bay, (b) the condition of the pollutants (biogeochemical), (c) alternative disposal methods, and (d) dredging technology. The study elements are intended first, to identify the problems associated with dredging and disposal operations and, second, to address the identified problems in terms of mitigation and/or enhancement. The division into separate but inter-related study elements provides a greater degree of expertise and flexibility in the Study.

This report presents the findings of Appendix H, Pollutant Uptake. The overall study will be the basis for preparation of a composite Environmental Impact Statement for Dredging Activities in San Francisco Bay System. A draft final report on the entire study is scheduled for completion in December 1975.

The following is an index of appendices to be published in the Dredge Disposal Study:

APPENDIX	REPORT	DATE PUBLISHED
	FINAL REPORT	
A	Main Ship Channel (San Francisco Bar)	June 1974
B	Pollutant Distribution	
C	Water Column (Water Column-Oxygen Sag)	
D	Biological Community	August 1975
E	Material Release	
F	Crystalline Matrix	July 1975
G	Physical Impact	July 1975
H	Pollutant Uptake	September 1975
I	Pollutant Availability	
J	Land Disposal	October 1974
K	Marsh Development	
L	Ocean Disposal	
M	Dredging Technology	

CONVERSION FACTORS

If conversion from the Metric to the British system is necessary, the following factors apply:

LENGTH

1 kilometer (km)=10^3 meters=0.621 statute miles=0.540 nautical miles
1 meter (m)=10^2 centimeters=39.4 inches=3.28 feet=1.09 yards=0.547 fathoms
1 centimeter (cm)=10 millimeters (mm)=0.394 inches=10^4 microns (μ)
1 micron (μ)=10^{-3} millimeters=0.000394 inches

AREA

1 square centimeter (cm^2)=0.155 square inches
1 square meter (m^2)=10.7 square feet
1 square kilometer (km^2)=0.386 square statute miles=0.292 square nautical miles

VOLUME

1 cubic kilometer (km^3)=10^9 cubic meters=10^{15} cubic centimeters=0.24 cubic statute miles
1 cubic meter (m^3) =10^6 cubic centimeters=10^3 liters=35.3 cubic feet=264 U.S. gallons=1.308 cubic yards
1 liter=10^3 cubic centimeters=1.06 quarts=0.264 U.S. gallons
1 cubic centimeter (cm^3)=0.061 cubic inches

MASS

1 metric ton=10^6 grams=2,205 pounds
1 kilogram (kg)=10^3 grams=2.205 pounds
1 gr (g)=0.035 ounce

SPEED

1 knot (nautical mile per hour)=1.15 statute miles per hour=0.51 meter per second
1 meter per second (m/sec)=2.24 statute miles per hour=1.94 knots
1 centimeter per second (cm/sec)=1.97 feet per second

TEMPERATURE

Conversion Formulas $\quad {}^\circ C = \dfrac{{}^\circ F - 32}{1.8} \quad {}^\circ F = 1.8({}^\circ C) + 32$

PREFACE

The heavy metal concentrations found in indigenuous organisms in San Francisco Bay are known to be higher than organisms of more pristine areas. This is probably a direct result of the storm runoff, municipal and industrial loadings of the Bay. The sediments of an estuary are known to be a repository of contaminants introduced into the system. During dredging and disposal operations these sediments are resuspended possibly increasing the likelihood of organism uptake. One of the primary considerations in evaluating such a phenomena is to know the mode of uptake of contaminants by organisms. The Crystalline Matrix Study, Appendix F, investigated the desorption of heavy metals from sediments and influence on ambient water-metal concentrations. The objective of the Pollutant Uptake Study was to investigate the mode of pollutant uptake and determine if dredging operations influenced the trace metal composition of resident species in a project area.

This objective was met via a field study of dredging operations in Mare Island Strait and a laboratory study. The study was arranged in four sequential steps. The steps included in the study are (1) the population structures dynamics and seasonal fluctuation of the most common invertebrate benthic and intertidal forms before, during, and after dredging operations in Mare Island Strait, (2) the heavy metal composition of the most abundant invertebrates in the dredge site collected prior, during and after the dredging operations, (3) monitoring of mussels (Mytilus edulis) transplanted into the dredged area, and (4) a laboratory investigation of direct uptake and accumulation of heavy metals. Each of these steps are interrelated and were conducted in the outlined sequence. The study, although focused on the Mare Island Strait area, was designed as a system for observing fluctuations in the population structure and heavy metal composition due to both natural and man-induced environmental modifications.

During the period of the field study, the two heaviest rainfalls of the year occurred at the same time as the dredging operations. Increases in the heavy metal body burden of the monitored species occurred during these periods. However, the trends in accumulation were the same for all the stations, both juxtaposition to the operation and outside of the project area. If the resulting accumulations were the result of the dredging operation, gradient would have been produced with the highest accumulations being in the vicinity of the most intense dredging activity (Steffen's). No such gradient was apparent. The laboratory investigations showed that uptake was significantly greater in low salinity water than in high salinity water. It appears that the rainfall which lowered the salinity level in the water in Mare Island Strait significantly, and the storm runoff which provided the source of heavy metals, were probably responsible for organism metal accumulation.

The results of this study will be integrated with the results of the Water Column Study, Appendix C; Crystalline Matrix Study, Appendix F; and, the

Pollutant Availability Study, Appendix I; to ascertain the influence of dredging and disposal operations on the contaminant levels of San Francisco Bay organisms.

UCID- 3666 Rev.

HEAVY METAL UPTAKE STUDY

FINAL REPORT

SUBMITTED TO

U.S. ARMY CORPS OF ENGINEERS

BY

LAWRENCE BERKELEY LABORATORY
ENERGY & ENVIRONMENT DIVISION
AND
BODEGA BAY INSTITUTE OF POLLUTION ECOLOGY

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June 1975

HEAVY METAL UPTAKE STUDY

ABSTRACT

Dredging operations in Mare Island Strait in northern San Francisco Bay were examined between September, 1973 and May, 1974 to determine whether these operations release toxic heavy metals from the dredged sediments, resulting in elevated concentrations of these metals in adjacent sediments and invertebrate populations.

Concentrations of the metals silver, arsenic, cadmium, copper, mercury, nickel, lead, selenium and zinc were monitored prior to, during and after two dredging periods. Metal concentrations were measured in sediments, and the native invertebrates *Macoma balthica*, *Neanthes succinea*, *Ampelisca milleri*, *Mytilus edulis* and *Ischadium demissum*. *Mytilus edulis* transplanted into Mare Island Strait from Tomales Bay, a relatively undisturbed area on the California coast, were also monitored. Samples were collected at stations established immediately adjacent to the dredge zone, and at stations located outside of the area exposed to dredging activity.

Changes in the mean metal concentrations in sediments and invertebrates during the study period were relatively small, considerably less than an order of magnitude. Mean metal concentrations in sediments and benthic invertebrates changed by less than a factor of two and changes in metal levels in *M. edulis* were no

greater than a factor of three.

The two dredging periods coincided with the two heaviest rainfalls of the year, and the resultant freshwater runoff caused significant changes in the salinity and particulate load in Mare Island Strait. It was, therefore, not possible to determine whether changes in metal concentrations at stations within the dredge zone were caused by either dredging or rainfall phenomena. However, changes in metal levels at stations outside of the dredge zone were of comparable magnitude and direction to those exposed to dredging activity.

The data indicate that dredging activity within Mare Island Strait did not significantly affect the concentration of heavy metals in adjacent sediments and in local invertebrate populations.

Monitoring of lead concentrations in suspended particulates and in centrifuged water samples obtained in the vicinity of the dredge area before, during and after the operations, showed a significant increase in lead concentrations in uncentrifuged water samples and in the suspended particulates during the first dredging period. Comparable changes were not observed during the second dredging period, suggesting that the observed changes resulted from surface runoff.

Uptake and accumulation of the chloride salts of silver, cadmium, copper, lead, and mercury by the clam *Macoma balthica*, were examined in a laboratory study. Exposure to three concentrations

of these metals under three salinity regimes, demonstrated uptake above pre-exposure levels and that lower salinities were associated with higher levels of accumulation.

ACKNOWLEDGMENTS

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

Figures:

INTRODUCTION

Maintenance dredging of Mare Island Strait, Vallejo, California, in northern San Francisco Bay, has been undertaken twice annually by the U.S. Army Corps of Engineers for many years. The Strait, approximately 3 kilometers in length, is bordered on the west shore by the Mare Island Naval Shipyard and by the city of Vallejo on the east shore. Mare Island Strait (MIS) receives water from the Napa River and tidal action introduces water from Carquinez Strait. Sediments deposited in the Strait from these inputs may, therefore, contain toxic heavy metals from both urban and industrial waste waters.

During dredging operations in MIS a certain amount of sediment resuspension occurs, but careful operation of a hopper dredge minimizes the input of resuspended sediments into local waters. This resuspended material is a potential source of heavy metals and other pollutants to local food webs, particularly to invertebrates exposed to suspended particulates or living in adjacent sediments. The possibility that dredging activities in San Francisco Bay may increase heavy metal concentrations in the biota has prompted the San Francisco District of the Corps of Engineers to sponsor studies on the impact of dredging on pollutant release. The present report presents the results of a one-year study of the effects of dredging activities in MIS on the levels of nine metals in local invertebrates, and in adjacent sediments.

Studies by the U.S. Geologic Survey have examined the distribution of mercury and of lead and copper in surface sediments of San Francisco Bay (McCulloch et al., 1971; Peterson et al., 1972). Haupert (1972) reported concentrations of several heavy metals in sediments collected from Mare Island Strait and Moyer and Budinger (1974) determined Cd levels in Mare Island sediments as part of their San Francisco Bay shoreline sediment study. An excellent review of the metal content of San Francisco Bay sediments was presented in the final report of the Crystalline Matrix Study (Anonymous, 1975).

The sediments of San Francisco Bay appear to be a significant sink for metals which have been introduced into the waters of the Bay as a result of various human activities. Whether dredging activities mobilize a significant fraction of these metals has been a subject of controversy (Gustafson, 1972; Jernelöv and Lann, 1973; Turekian, 1974). The studies and reviews carried out to date on the environmental effects of dredging activities have provided relatively little information on this topic.

Surveys such as those conducted by the National Marine Fisheries Service (1972) on dredge disposal in New York Bight, by May (1973) on hydraulic dredging in Alabama estuaries, and by Brehmer (1967), Biggs (1968), Flemer et al. (1968), and Pfitzenmeyer (1970) on environmental effects of dredging in Chesapeake Bay, have examined only the gross physical and biological effects of dredging operations.

Studies conducted by Cable (1969), Wennekens (1972), Turekian *et al*. (1971) and by Gordon (1974) on the environmental consequences of dredge spoil disposal have included proposals for reducing the potential, detrimental effects of spoiling operations. Concise overviews of the environmental aspects of estuarine dredging and spoiling practices are presented by Windom (1972) and by Turekian (1974).

Other studies concerning specific environmental effects of dredging activities are listed or reviewed in compiled bibliographies, such as those by Sherk and Cronin (1970), Bohlen and Devine (1973), and Morton (1973), or in annotated bibliographies such as that prepared by Metcalf and Eddy (1968).

The present study attempted to monitor heavy metal concentrations in sediment and invertebrates during two dredging operations; and through a series of field and laboratory experiments to determine whether these operations significantly affect the concentration of metals in local invertebrate populations.

MATERIALS AND METHODS

I. Rationale of Study and Experimental Design

The present study was designed to determine the natural fluctuations in the concentrations of nine heavy metals in invertebrates and sediment in MIS and to compare these fluctuations to changes observed during and after the two scheduled dredge periods.

Benthic and intertidal stations and organisms were selected on the basis of a pre-survey conducted in this area prior to the first dredge period. Sampling stations were subsequently established both within the dredge zone and outside of the vicinity of planned dredging activity. This station arrangement allowed changes observed within the dredge zone to be compared to those observed at stations outside of the immediate influence of dredging operations. It was felt that by this method, natural, seasonal fluctuations in metal levels could be separated from possible fluctuations due to dredging.

Since maintenance dredging has been conducted in MIS for many years, it was possible that native *M. edulis* may have reached some pollutant equilibrium whereby increases in the test metals would not be observed. To test this possibility and to gather data on the rate of metal uptake and accumulation in a filter feeding invertebrate, the mussel *M. edulis* was transplanted from Tomales Bay to stations within and outside of the dredge zone in MIS.

The clam, *M. balthica*, was used in a laboratory experiment

to determine the effects of salinity and the concentration of metals in ambient water on the uptake and accumulation rate of these metals.

II. Pre-Survey Collections

A pre-survey was conducted during July-September, 1973, to gather basic information on the taxonomy, abundance, and distribution of subtidal and intertidal invertebrates in Mare Island Strait (Fig. 1, p. 6). Sediment and invertebrate samples were collected to determine the concentration ranges of the metals Ag, As, Cd, Cu, Hg, Ni, Pb, Se and Zn. These data were used to check instrument sensitivity and to establish subsequent sample handling procedures.

Benthic samples were collected for metal and population analyses by a corrosion-free, stainless steel, $0.05m^2$ Van Veen grab. Three population and three metal samples were collected at each of the following nine pre-survey stations: NI (N = north, I = inner or shallow, 1 meter), NO (N = north, O = outer or deep, 6 meters), SI, SO, DO, EI, EO, WI, and WO (Fig. 1). Aliquots of surface sediments (<2.0 cm) were removed from each of the three metal samples, immediately frozen and returned to the laboratory for later analysis. The remainder of the grab sample was washed on a 1.0 mm mesh stainless steel screen and collected invertebrates were frozen for later metal analyses.

All population samples were washed through a 1.0 mm mesh screen, and the retained organisms preserved in 10% formalin for later sorting, identification, and counting.

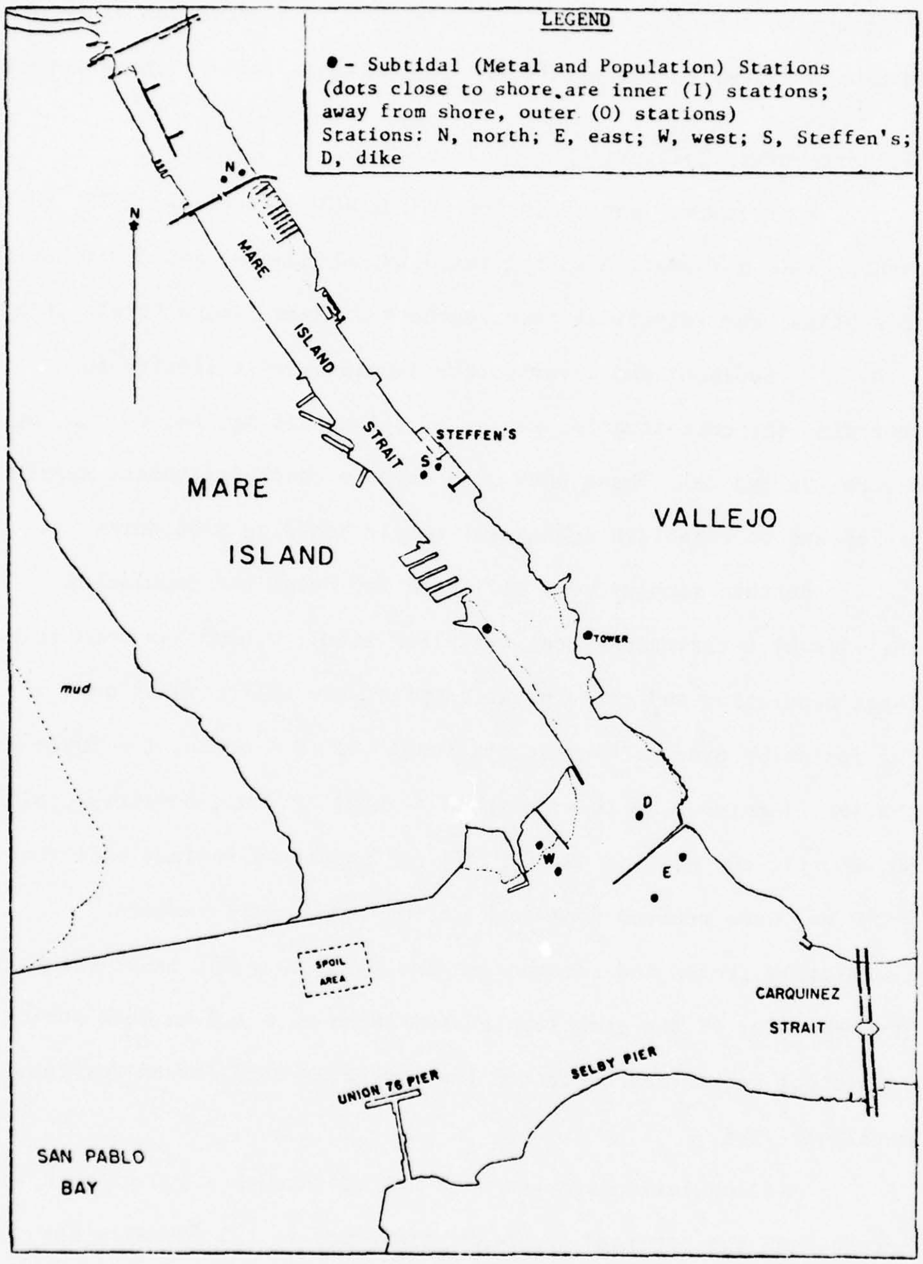

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Figure I. Pre-survey (July 28-September 5, 1973) Collection Stations

During the pre-survey, 20 M. edulis were collected from Marconi Cove on the east shore of Tomales Bay (Fig. 4, p.15) and transplanted to station SI to test transplant bag design and mussel survival rates.

III. Dredge Period Collections

A. Subtidal Biological Collections

The nine pre-survey benthic stations were judged to be suitable in terms of faunal similarity and abundances for continued monitoring. Four additional stations were chosen for study and were designated TI, TO, DI, and SP (Fig. 2, p.8). The additional stations were selected to provide the best spatial coverage, within practical limits, of the dredge zone and adjacent areas including the spoil site (Station SP).

Pre-survey collections showed that the most abundant, suitable benthic species for metals analyses were the clam, Macoma balthica (Bivalvia: Mollusca), the worm, Neanthes succinea (Polychaeta: Annelida) and the amphipod, Ampelisca milleri (Crustacea: Arthropoda). The Van Veen grab used in the pre-survey, although a good remote sampler, was unable to efficiently collect the large numbers of individuals necessary to accurately determine fluctuations in metal concentrations in the above species. A specially-designed, diver-operated, suction dredge, constructed of PVC plastic pipe and similar to those used in underwater mining operations, was used to collect the large number of benthic invertebrates necessary for metals

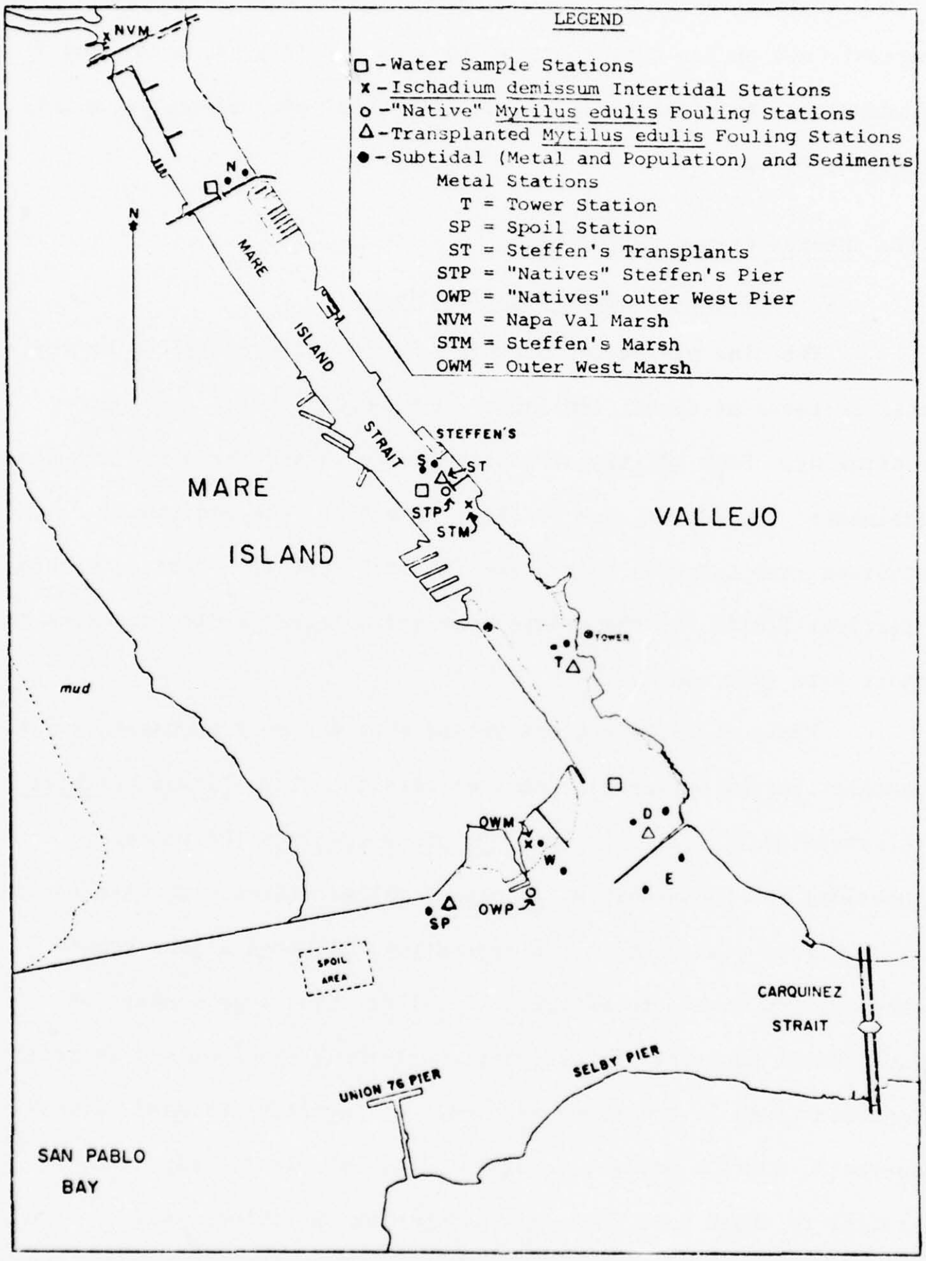

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Figure 2. First Dredge Period (October 29 - November 19, 1973) Collection Stations

analyses. To eliminate possible metal contamination, all dredge parts, hoses, and fittings were constructed of either PVC, Teflon, or nylon (Nytex).

The 16 cm diameter x 100 cm long dredge was connected to a 7,800 liter/minute water pump which forced water through the dredge, creating the necessary suction. The discharge end of the dredge was coupled to a 1.5 m long, 1.0 mm mesh Nytex bag which retained invertebrates and some sediment. Samples obtained with this device were emptied into large plastic bags and later washed through a 2.0 mm mesh pre-screen and into a 1.0 mm mesh final screen. Both screens were constructed of stainless steel mounted in aluminum frames.

Specimens of *M. balthica*, *N. succinea*, and *A. milleri* were separated in the field and returned alive to Lawrence Berkeley Laboratory in oxygen-filled plastic bags. The live *M. balthica* and *N. succinea* were removed from remaining detritus, placed in separate acid-washed plastic trays filled with aerated Mare Island water, and allowed to purge their digestive tracts for three days. The water was changed at least once during this period.

In the field *A. milleri*, averaging 5 mm in length, were removed from unwashed samples by stirring them to the water surface where they were entrapped by the surface tension. They were then skimmed from the surface by fine mesh nylon screening and returned alive to the laboratory in oxygen-filled bags. In this manner, adequate numbers were obtained for replicate analyses. After returning to the laboratory, the amphipods were refloated to the

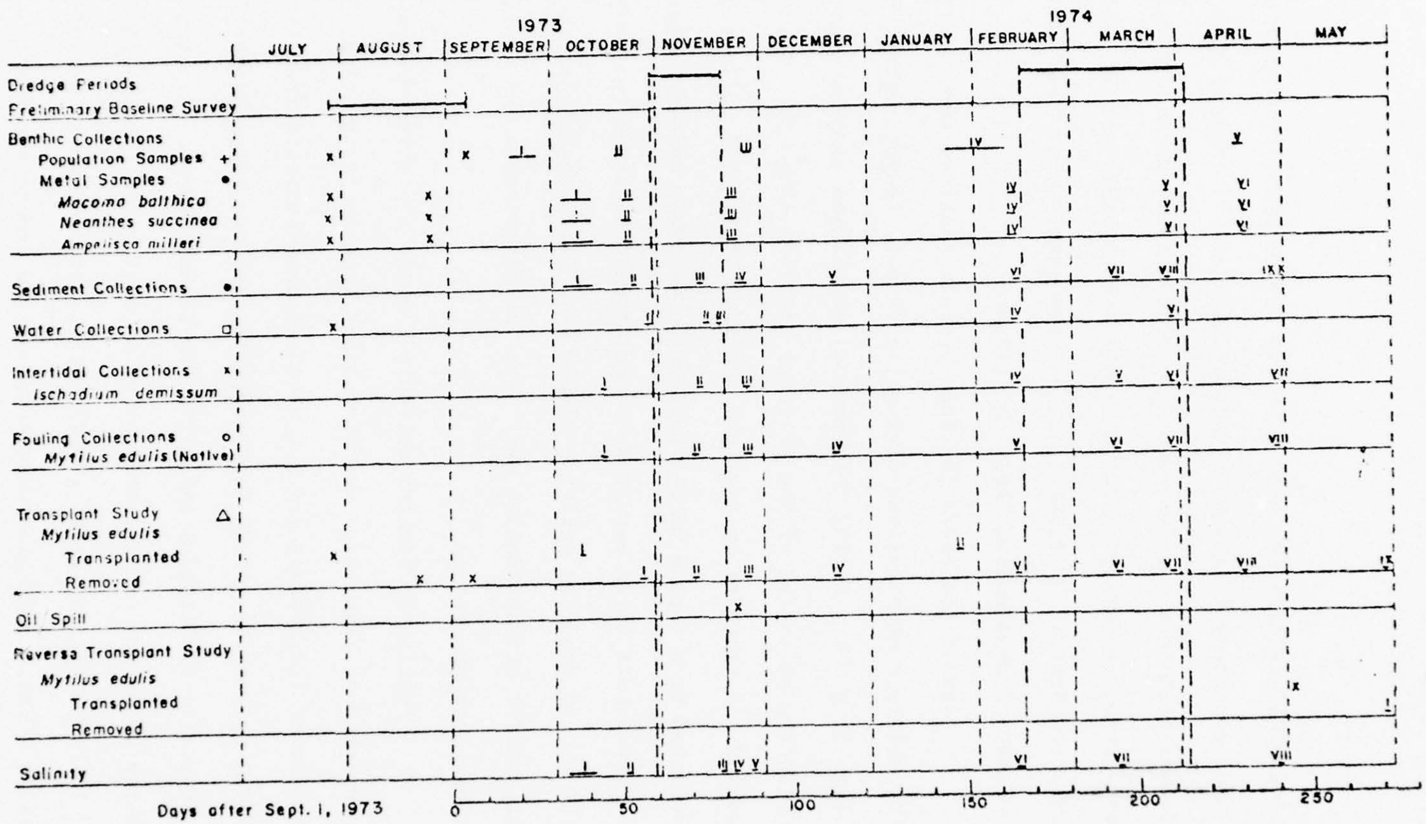
water surface in clean plastic trays and poured onto nylon mesh screening, further separating them from remaining detritus. No attempt was made to purge this species due to high mortality at this stage of sample preparation.

Benthic population samples were collected by divers using PVC plastic cores rather than by the Van Veen grab, since cores allowed uniform substrate penetration, the collection of a greater number of random samples of equal volume and surface area, and reduced the amount of sediment to be screened and sorted. Large cores (10.2 cm diameter x 30 cm length) were used to collect M. balthica and N. succinea for population analyses. Small cores (7.6 cm diameter x 12 cm length) were used to collect A. milleri. The large cores were washed through a 1.0 mm mesh screen and the small cores washed through a 0.42 mm mesh screen. Invertebrates retained on these screens were preserved in 10% formalin for later sorting, identification, and counting. Specimens were eventually transferred to 10% ethyl alcohol for future reference.

Two dredge periods were scheduled during this study. The first dredge period lasted 20 days (29 October - 19 November, 1973) and the second lasted 48 days (13 February - 2 April, 1974). The subtidal biological sampling schedule is presented in Table 1, p. 11. The collections bracketed the two dredge periods but differed in their timing and in the stations monitored.

The first dredge period was preceded by two subtidal

TABLE I. FIELD COLLECTION SCHEDULE



biological collections just prior to the dredging operation which was immediately followed by a third subtidal biological collection. It was felt that possible short term changes of metal concentrations as a result of dredging could be observed by this method. All thirteen benthic stations (Fig. 2) were sampled for both metal and population data during these collections.

Six of the above thirteen benthic stations were monitored for metals concentrations during the second, longer, dredge period (Fig. 3, p. 13). During this period, population samples were collected at twelve of the previous stations (Fig. 3). This dredge period was preceded by a single subtidal biological collection, followed by a second metals collection one week before dredging ceased, and a third metals and population collection two weeks after the end of dredging activity (Table 1). This schedule was designed to monitor both potential short term metal releases and possible subsequent desorption.

Population samples collected during the first dredge period consisted of five large and five small samples per station. The number of large cores per large sample was increased from two for the first collection (18-24 September) to four per large sample for the second (19-22 October) and third (26-28 November) collections. Eight large cores per sample were collected during the fourth (15 January - 13 February) and fifth (16-17 April), second dredge period collections. These increases were necessary to reduce the number of

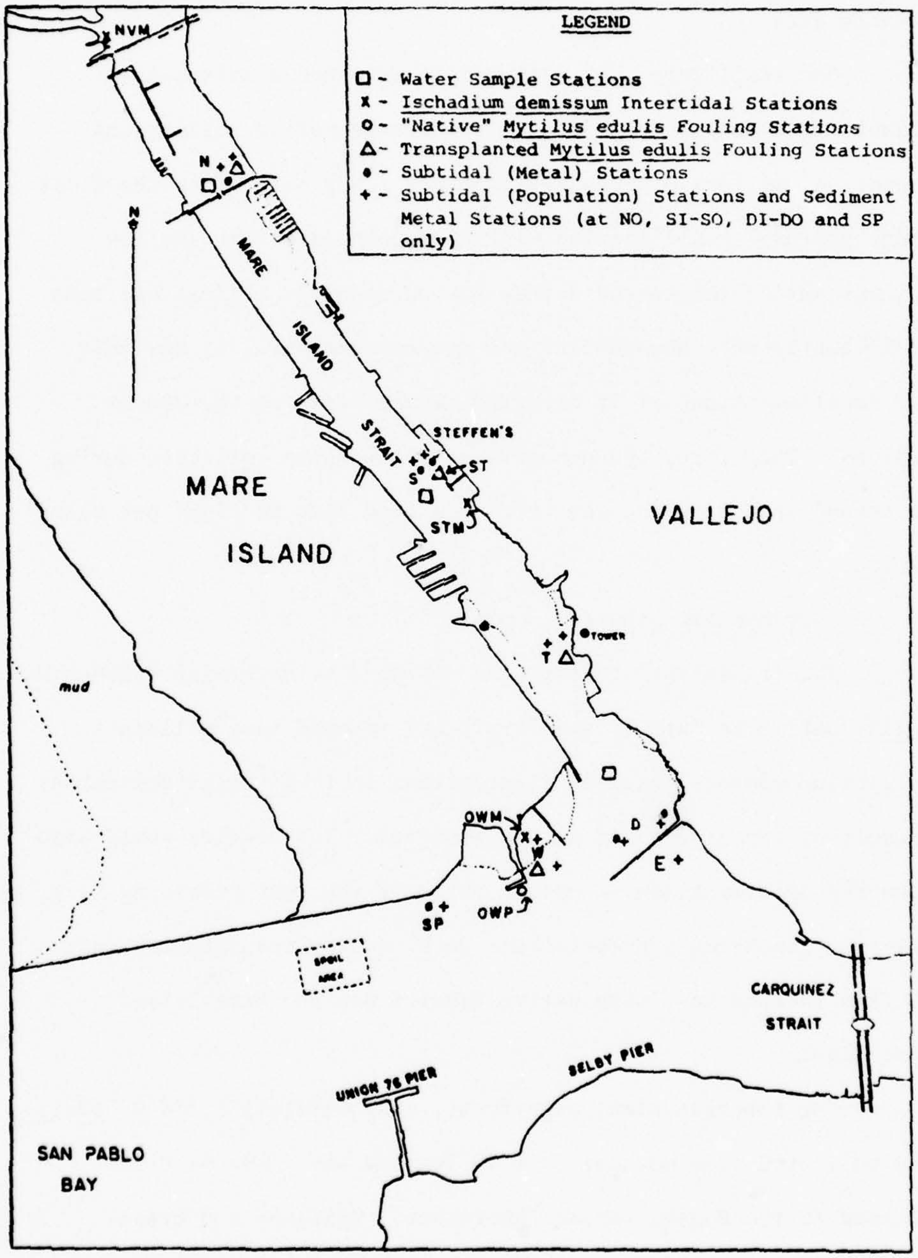


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Figure 3. Second Dredge Period (Febuary 13 - April 2, 1974) Collection Stations.

samples with zero specimens thereby providing more statistically reliable data.

One small core per small sample provided statistically reliable data during the three, first dredge period collections. However, *A. milleri* disappeared from the study site after the first dredge period. Small samples were discontinued at the shallow stations during the second dredge period since *A. milleri* had been significantly more abundant at the deeper stations. It was felt that recolonization, if it occurred, would begin at the deeper stations. Therefore, the number of small samples collected during the second dredge period was increased from five to eight per outer station.

B. Transplant Studies

The transplant studies were designed to determine whether *M. edulis*, native to Mare Island Strait had reached some pollutant equilibrium whereby possible fluctuations in their metal content as a result of dredging would not be detected. The studies would also allow the determination of uptake rates of the test metals by *M. edulis* by comparing concentrations in *M. edulis* transplanted into MIS from Tomales Bay, with native Tomales Bay and Mare Island populations.

For the transplant experiment, approximately 1,200 *M. edulis* were collected from Marconi Cove in Tomales Bay (Fig. 4, p. 15) and returned to the Bodega Marine Laboratory. Epifauna and byssal

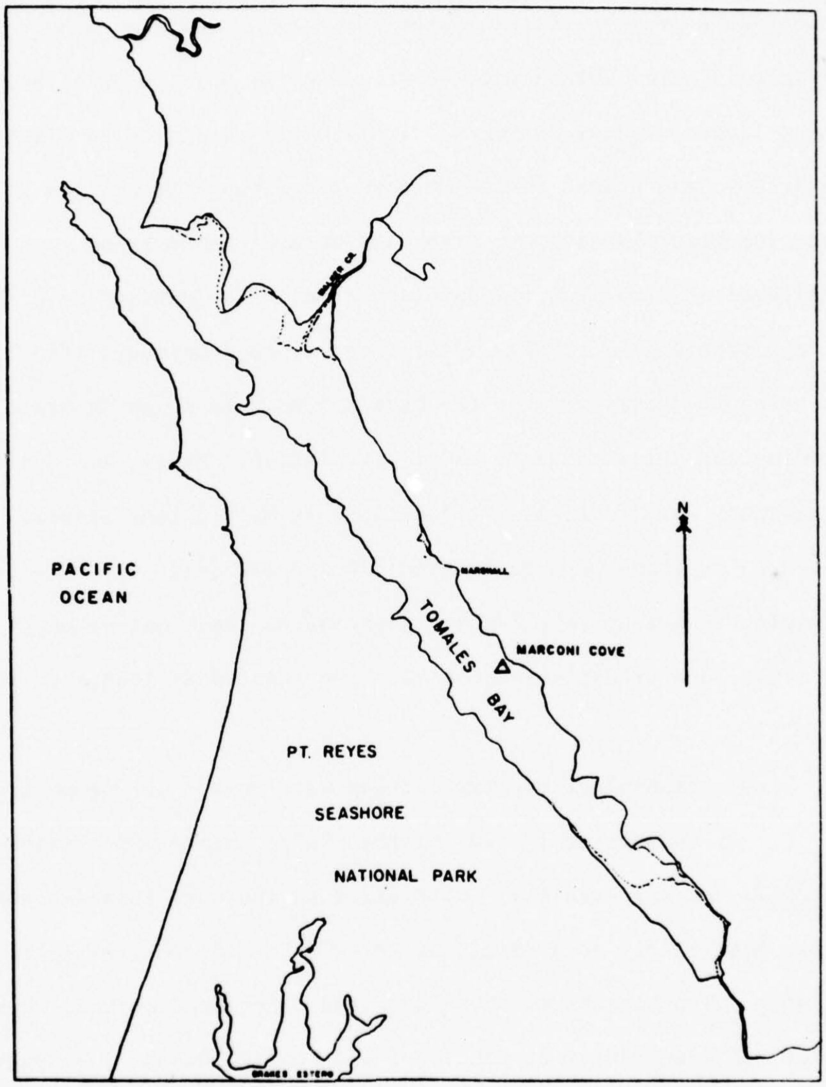

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Figure 4. Transplant Station in Tomales Bay
Δ- Transplanted *Mytilus edulis*.

threads were removed and the mussels sorted into four size classes (30-40, 40-50, 50-60, and 60-plus mm in length). Fifty of these mussels were prepared for analyses as baseline samples. The remaining mussels were divided into 45 groups of 25 mussels each; all groups included equal numbers of individuals of each size class. The groups were placed in 1.0 mm mesh Nytex bags (50 cm long x 15 cm high) for transplantation. Nine bags were attached below mean low tide level at each of the transplant sites: TB (Marconi Cove) (Fig. 4); and stations SP, D, T, and ST (Fig. 2) on 8 October, 1973. Care was taken to evenly arrange the bags and mussels so as to avoid crowding and allow adequate water circulation. Native _M. edulis_ populations were found at two locations in Mare Island Strait. These two stations were designated STP and OWP (Fig. 2). Two of the transplant stations were located adjacent to these native populations and native and transplanted mussels were removed as indicated in Table 1.

One transplant bag per station was removed during collections I - IV. By collection IV (19 December 1973) native and transplanted _M. edulis_ had suffered high mortalities at the Mare Island transplant sites, most likely as a result of heavy rainfall and greatly reduced salinity. Transplants at station SP and D appeared normal, however 60% of the transplants at station T and nearly 100% of the transplants at station ST were dead. Native mussels at station OWP in Carquinez Straits appeared normal, but less than 20 native

individuals remained alive at station STP. An oil spill occurred in MIS on 20 November 1973, and the presence of an oily coating on transplant bags and pilings could have contributed to this mortality. The mussels transplanted to the Tomales Bay site continued to have zero mortality throughout the experiment. The five remaining transplant bags at stations ST, T, D, and SP were removed in collection V due to high mortalities at these stations.

Due to the high mortality of the Mare Island transplants after the first dredge period a second transplant experiment was initiated on 24 January 1974 to monitor the second dredge period. Mussels were again collected from Marconi Cove, Tomales Bay (Fig. 4), and a second Tomales Bay baseline was determined. Sixteen bags with 25 mussels per bag were transplanted to the stations NO, SO, TO, WO (Fig. 3).

Transplants were removed according to the schedule presented in Table 1. During transplant collection V, one bag was removed from stations NO, SO, and TO. All mussels transplanted to station NO were dead by collection VI; all remaining bags at stations SO and one bag from station WO were removed during this collection. One bag was removed from station WO during collection VII and the two remaining bags were removed in collection VIII. All transplant samples were returned alive to Lawrence Berkeley Laboratory for purging and sample preparation.

C. M. edulis Desorption Study

Higher concentrations of the test metals were observed in M. edulis native to Mare Island, than in those collected in Tomales Bay. To determine whether desorption of metals could occur in M. edulis a number of mussels were collected from the Selby Pier (Fig. 3) and transplanted to Tomales Bay. The Selby Pier area had been the site of a lead smelter and in previous studies high concentrations of several heavy metals were observed in M. edulis from this area.

A baseline group of these mussels was prepared for analysis and another group was transplanted to Marconi Cove, Tomales Bay on 4 May 1974. The Tomales Bay reference samples and the Selby transplants were removed for analysis and comparison on 29 May 1974.

D. Intertidal Biological Collections

Populations of the ribbed mussel, Ischadium demissum were found at three locations in the Mare Island Strait area. The three intertidal marsh stations were labeled NVM, STM, and OWM (Fig. 2). Samples of 25 mussels per collection were removed from these sites according to the collection schedule (Table 1). This animal lives semi-buried in sediments but is a suspension filter feeder similar to M. edulis. Their habitat makes them more susceptible to exposure to metal rich suspended sediments, resuspended by wind and wave action or by dredging-spoiling operations. Collected samples were returned alive to Lawrence Berkeley Laboratory for purging and sample preparation.

E. Sediment Collections

Sediment samples were collected by divers at the subtidal stations during the subtidal biological collections as presented in Table 1. Small, plastic vials were used to collect a sample of the upper 2 cm of sediment at each station to monitor possible fluctuations in the concentration of metals in newly deposited sediment layers. Collected sediments were returned to Lawrence Berkeley Laboratory and immediately frozen for later analyses.

F. Water Collections

Water samples were collected for the determination of dissolved Pb and Pb associated with suspended particulates. Samples were collected during ebb tide from a depth of 4 meters at three mid-channel locations in Mare Island Strait (Fig. 2). This procedure was employed to obtain samples representative of natural conditions and as free as possible of shallow water inputs. Water samples were collected by divers using 4 liter, acid-cleaned, polyethylene bottles which were transported through the water surface in sealed plastic bags. Collections were made before, during and after the first dredge period and before and during the second dredge period. Samples taken during the dredge periods were collected downstream from the dredge zone, behind the operating dredge, and upstream from the dredge zone.

G. Rainfall Data and Salinity Determination

Daily rainfall data for the period September, 1973 - May, 1974 was obtained from the Meterological Service of the Mare Island

Naval Shipyard.

Salinity measurements were determined by silver chloride titration (Strickland and Parsons, 1972) in water samples collected at stations NO, SO, DO, TO, and WO (Fig. 2) throughout the study period.

IV. Laboratory Uptake and Accumulation Experiment

A laboratory experiment was conducted at the Bodega Marine Laboratory (BML) to determine whether *M. balthica* could accumulate heavy metals directly from water and to determine the effects of concentration and salinity on uptake rates.

A diagrammatic representation of the laboratory design is presented in Figure 5, p. 21. The test tanks, holding tanks, reservoir tank and all water lines were constructed of acid-cleaned polyethylene or PVC plastic. Filtered water was obtained from the BML seawater system and refiltered through a polyethylene-polyurethane foam filtration unit. Seawater was diluted in the reservoir tank to a salinity of 25$^{o}/_{oo}$ with deionized water. This initial salinity represented the upper range of values observed in Mare Island Strait.

The system was designed to simultaneously expose *M. balthica* to three salinities and to three concentrations of the metals Ag, Cd, Cu Hg, and Pb added as chloride salts. The concentrations of metals in, and the salinity of, the water entering the 12 test tanks were controlled by the flow rate of the primary solutions entering the

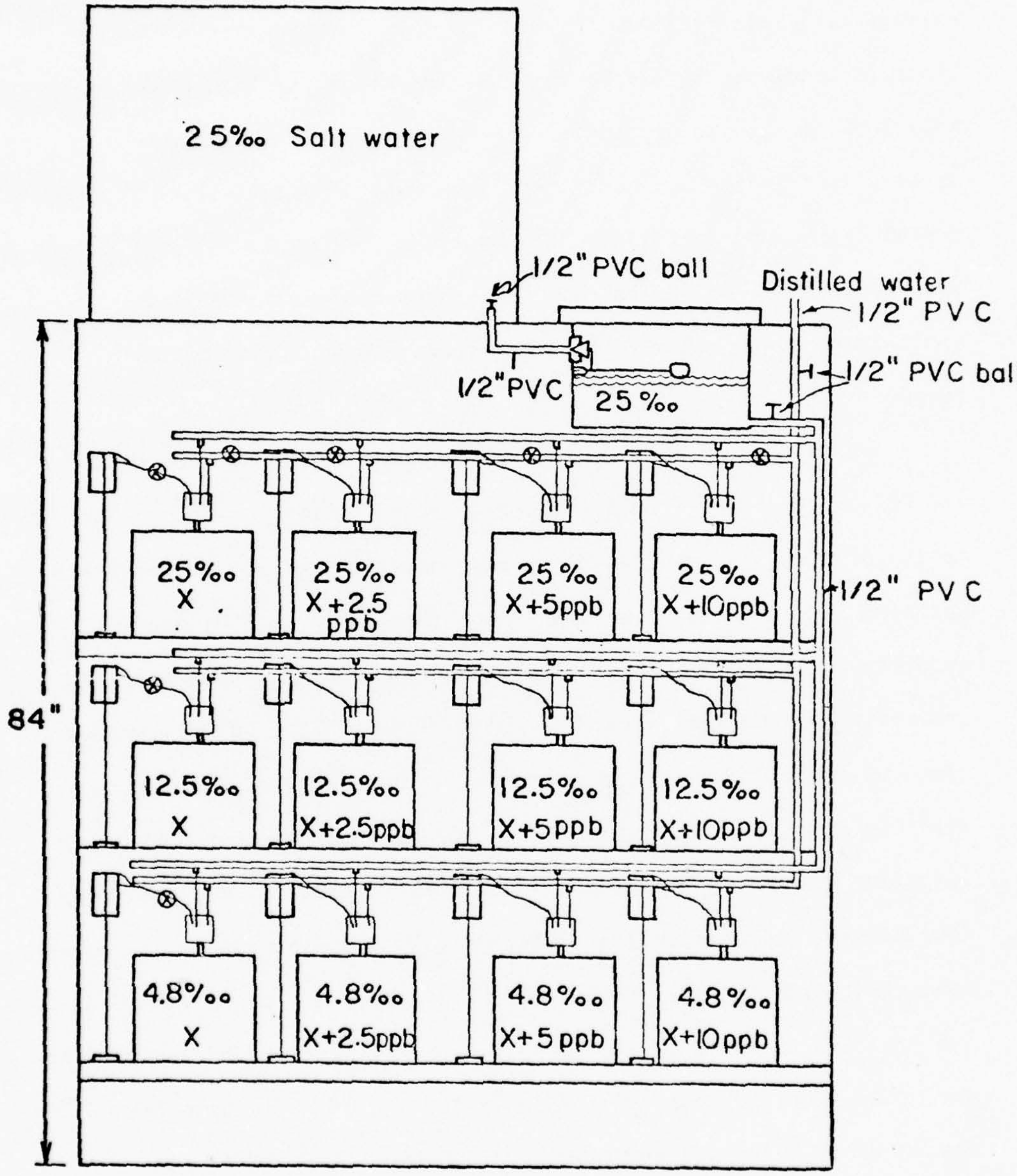

Figure 5. Diagram of laboratory uptake experiment.

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various pre-mixing chambers. Three of the 12 tanks were used as controls receiving waters of three different salinities but no additional metals. The remaining tanks each received water of a particular salinity and added metal content. The salinities in the twelve tanks were as follows: tanks 1-4 = 25^{o}/oo; tanks 5-9 = 12.5^{o}/oo; tanks 9-12 = 4.8^{o}/oo. These values represented the approximate range of salinities observed in Mare Island Strait during this study.

Three stock solutions of the divalent metals Ag, Cd, Cu, Hg, and Pb were prepared from the chloride salts of these metals. The stock solutions had the following concentrations of the three metals: solution A (low) = .25 ppm; solution B (medium) = .5 ppm; and solution C (high) = 1.0 ppm. These solutions were dripped into the pre-mixing chambers at a rate of approximately 0.1 ± .01 ml/min and combined with 10.0 ± .1 ml/min of water of one of the above salininities to provide a flow rate of 10.1 ml/min into the test tanks. The resultant concentrations of the three metals entering the test tanks were assumed to be as follows: tanks 1, 5, 9 = X or control seawater concentrations; tanks 2, 6, 10 = X + 2.5 ppb; tanks 3, 7, 11 = X + 5.0 ppb; and tanks 4, 8, 12 = X + 10.0 ppb. The three concentrations were chosen on the basis of the determination of Pb in Mare Island Strait water which was approximately 5.0 ppb. This value was bracketed by the two additional concentrations. The concentrations of the other metals were equivalent to the Pb concentrations and

were based on the reported seawater values presented by Goldberg (Horne, 1969). Water entering the test tanks from the pre-mixing chambers was continuously mixed and aerated by a diagonally flowing cross current, maintained by an air-injected venturi system.

Approximately 1,000 _M. balthica_ were collected from station SC in MIS (Fig. 2) for exposure in this continuous flow system. The clams were allowed to purge for three days in filtered, $15^{o}/oo$ seawater, then separated into 12 groups of 75 individuals and introduced into the test tanks. In addition, 25 purged clams were composited into 5 groups of 5 individuals each to establish a baseline metal concentration. After 3, 6 and 9 days exposure, 25 clams were removed from each tank and prepared for metals analyses as described below.

Although the metal concentration of the test solutions were not monitored, the relative exposure procedure followed in this study was considered valid to answer the above questions. Control or monitoring of pH, Eh, temperature, _in situ_ metal concentrations, chemical state of metals and other physical-chemical parameters which influence uptake and accumulation of heavy metals was not attempted due to severe time limitations and the lack of necessary analytical facilities.

V. Sample Preparations for Metals Analyses

A. Invertebrates

Benthic and intertidal invertebrates collected during this study were returned alive to Lawrence Berkeley Laboratory for

preparation and metal analyses. After purging, the tissues of M. balthica, M. edulis, and I. demissum were removed from their shells and placed in clean, plastic vials. The mussels were large enough for individual replicates, but it was necessary to analyze the clam M. balthica and the polychaete N. succinea as composite replicates with 3-5 individuals per sample.

A digestion step was necessary to break down the worm, clam and mussel tissues. Five to seven ml of the strong organic base, tetramethyl ammonium hydroxide (Eastman-Kodak, 0.006M) were added to each vial. The samples were then heated at 40°C for 8 hours. The solubilized samples were frozen, lyophilized for 36 hours, ground to a powder within the sample vials by a corrosion free stainless steel pestle and analyzed for Hg as described below. Frozen samples of A. milleri were separated into 2 gram (wet weight) replicates, lyophilized for 36 hours and ground to a fine powder. This material was then ready for Hg analyses.

B. Sediments

Sediment samples collected during this study were frozen immediately upon return to the laboratory for preservation and later analysis. Sediments were prepared for metals analyses by slightly thawing the frozen samples, and removing a 2-5 gram aliquot for freeze-drying. The dried sediments, including the suspended particulate samples, were ground to a fine powder in an agate, mortar and pestle and were then ready for Hg determinations.

C. Water

Samples were immediately returned to Lawrence Berkeley Laboratory and two 250 ml aliquots were removed from each sample after vigorous shaking. One aliquot of raw sample was centrifuged to remove suspended particulates (>.6μ esd = equivalent spherical diameter). The supernate was drawn off, adjusted to pH 2 with 12N 3x distilled (NBS) HCl and heated for three days at 55°C in sealed Teflon bottles. The supernate was then analyzed for Pb by anodic stripping voltametry (ASV) as described by Girvin et al. (1974). Lead in this supernate is referred to as Phase I Pb (Table 9, p.61), and represents that fraction of Pb which is soluble, plus Pb which is HCl acid extractable from both organic and inorganic suspended material (<.6μ esd) remaining in the supernate. The suspended sediments, removed by centrifugation, were collected, dried at 40°C to a constant weight and prepared for metals analyses as described below. Lead in these dried sediments represents the total Pb associated with suspended particulates in the water column and is referred to as Phase III Pb on a dry (μg/g) and wet (μg/l) weight basis (Table 9).

The second aliquot of raw water was immediately acidified to pH 2 with 12N, 3x distilled (NBS) HCl, and heated as above prior to analysis by ASV. Lead concentrations determined in these aliquots represent total Pb burden in the water column and are referred to as Phase II Pb concentrations (Table 9).

D. Sample Preparation for X-ray Fluorescence Analysis

Once the samples were ground to a fine powder, Hg could be determined in this material. For the analyses of Ag, As, Cd, Cu, Pb, Ni, Se, and Zn by X-ray fluorescence spectrometry, it was necessary to prepare thin wafers from the powdered sample. Samples were prepared by weighing out 150 mg of the invertebrate powder, pouring it into a special stainless steel, 300 mm diameter die and pressing the material into a wafer by hydraulic pressure. Sediment wafers were prepared by weighing out 75 mg of both the fine sediment powder and pure, powdered cellulose and grinding the two materials together in an acid-cleaned agate, mortar and pestle. The prepared wafer could then be analyzed on the X-ray fluorescence apparatus described below.

VI. Description of Instruments

The analyses of heavy metals in all samples of organisms, sediments, and suspended particulates were performed on the X-ray fluorescence spectrometry and Isotope-shift Zeeman atomic absorption, IZAA, systems at Lawrence Berkeley Laboratory. These instruments, although not yet widely used for environmental trace element analyses, offer a number of advantages for the analyses of a large number of samples for a series of metals. Both systems require relatively simple sample preparation and low sample weight. The X-ray fluorescence system allows the rapid analyses of several metals simultaneously. Over two samples per minute can be analyzed for Hg

by the Zeeman atomic absorption method.

A. X-ray Fluorescence Method

A semiconductor detector, X-ray fluorescence spectrometer was used for the determination of the elements, Ag, As, Cd, Cu, Ni, Pb, Se, and Zn in this study. This system employs a low power, tungsten (w)-anode, X-ray tube (30 watts) which is capable of operating at 80 KV. Additionally, interchangeable secondary targets are utilized to obtain near, monochromatic excitation radiation which enhances sensitivities over those obtainable by other X-ray systems.

Determination of the elements, As, Cu, Ni, Pb, Se and Zn were ascertained with a molybdenum (Mo) secondary target and a terbium (Tb) secondary target was used for the Ag and Cd analyses. Transmission measurements were made on representative samples of each invertebrate species and sediment type collected to determine the corrections necessary to compensate for matrix absorption effects (Giauque *et al*., 1973).

Data obtained on this system were recorded on magnetic tape and subtraction of scattered excitation radiation background, unfolding of X-ray line overlap, and concentration calculations with counting errors were carried out on Lawrence Berkeley Laboratory's CDC 7600 computer. A more detailed description of the theory and operation of this semiconductor detector X-ray system is presented by Jaklevic *et al*. (1973).

B. Isotope-Shift Zeeman Atomic Absorption

Mercury determinations in all biological, and sediment samples were performed on a new type of atomic absorption spectrometer developed by Dr. T. Hadeishi at Lawrence Berkeley Laboratory. This instrument allows the measurement of the Hg content of a solid or liquid sample in less than a minute without previous chemical separation of the Hg from the host material (Hadeishi and McLaughlin, 1971).

In this technique, the sample is thermally decomposed in a nickel furnace maintained at a temperature of 800°C. The decomposition products are swept into a heated absorption tube by oxygen carrier gas, where they are scanned by a light beam from a ^{204}Hg electrodeless-discharge lamp operated in a magnetic field. The light emitted from this lamp has two components; one has a wave length centered on the absorption profile of Hg in air, and the other is slightly displaced (less than 1 cm^{-1}) from the absorption line. The centered component is absorbed by mercury vapor, non-mercury decomposition products (smoke, particulates) and other thermally stable molecular species present. The slightly displaced component is absorbed only by the non-mercury background. In this system absorption due to mercury alone is measured by electronically taking the difference between the absorption of the two components. This background cancellation results in very low interferences even in fresh tissue samples. A fully detailed description of this system

is presented by Hadeishi et al. (1975).

During the present study over 5,000 Hg determinations have been made using this system. We have calculated the practical detection limit of Hg (limit at which results are reproducible at ±5%) with sample weights ≈5 mg, to be 0.01 ppm in lyophilized sediment and biological samples.

RESULTS AND DISCUSSION

I. Results of Rainfall and Salinity Measurements

Rainfall data over the period of study were provided by the Meteorological Service of the Mare Island Naval Shipyard. The data, integrated over five day intervals beginning 1 September 1973, are plotted in Fig. 6, p. 31 . The number of days after September 1 are plotted on the horizontal axis and the two dredging periods are indicated by crossbars. This graph shows that the two periods of heaviest rainfall coincided almost exactly with the two periods of dredging.

Salinity was measured in bottom water, water from 1 meter depth, and surface waters at various periods during the subtidal biological collections. The mean salinity values observed at all stations and times are presented in Fig. 7, p. 32 . Mean salinity values ranged from 13-20°/oo before the first rainfall period, with higher salinities being observed in 1 meter and bottom water samples. Salinity differences between surface and bottom waters were most pronounced at stations near the mouth of Mare Island Strait indicating greater stratification at these locations.

Salinity decreased significantly in surface, 1 meter, and bottom waters during the first dredging period. Values fell from 13°/oo in surface waters and 20°/oo in 1 meter and bottom waters to 4°/oo in surface and 1 meter water and to 9°/oo in bottom waters.

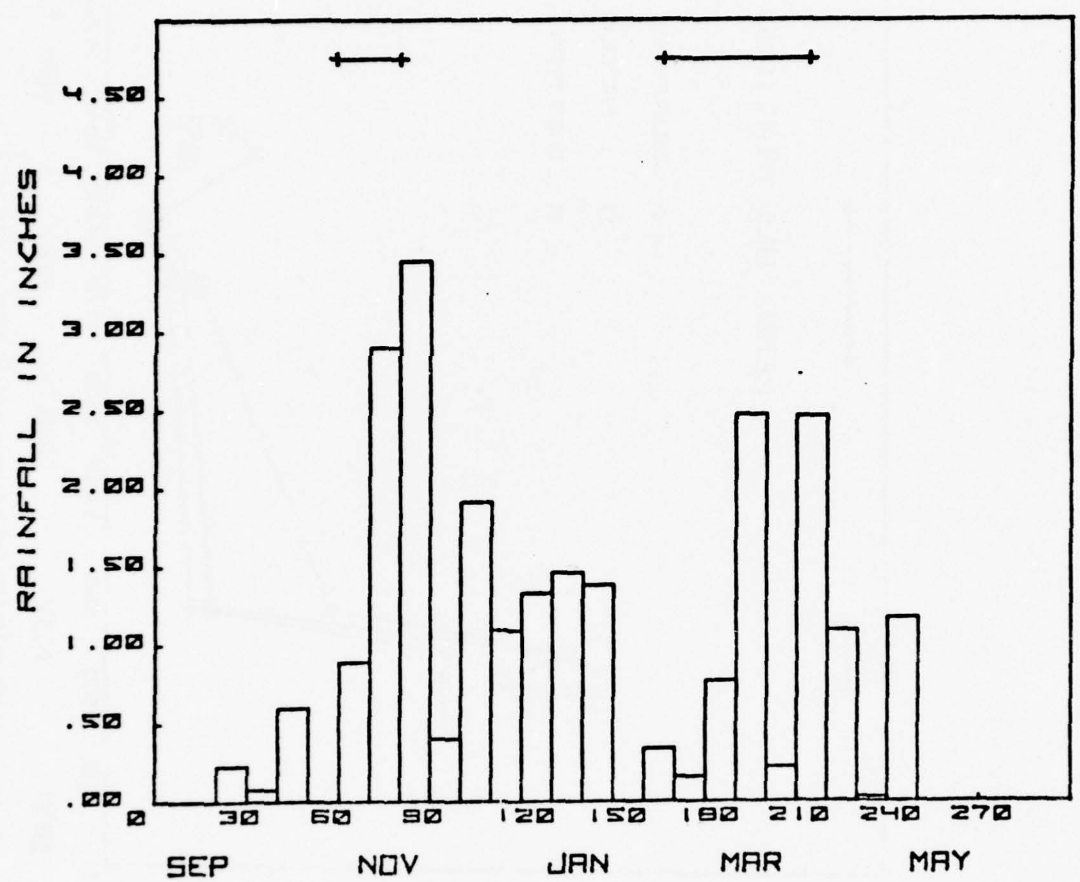

FIGURE 6. Rainfall data for period September 1973- May 1974.

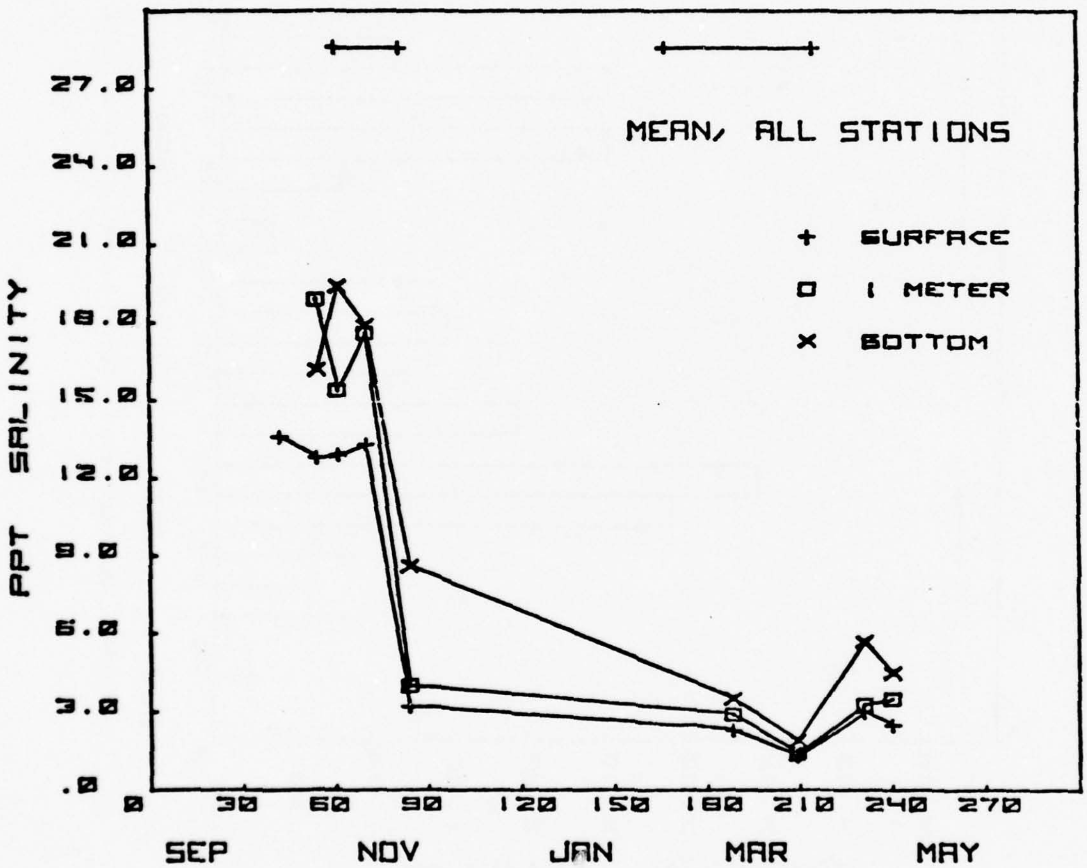

Figure 7. Mean salinity values recorded in Mare Island Strait.

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During the February collections, salinities uniformly averaged $3^{o}/oo$; lowered salinities ($1^{o}/oo$) were observed during the second dredging-rainfall period increasing to $4\text{-}5^{o}/oo$ after dredging-rainfall ceased.

The effect of salinity on the mobilization of metals has been studied by several workers (Bothner and Carpenter, 1972; Cranston and Buckley, 1972). These studies have shown that higher concentrations of some trace metals are associated with low chloride ion concentrations. It is possible that lowered salinity, as a result of heavy rainfall, and freshwater run-off may affect trace metal mobilization from sediments and influence suspended particualte sorption processes.

The heavy rainfall during the period of this study, no doubt, transported significant amounts of metal rich suspended particulates from street run-off and land drainage into Mare Island Strait.

II. Data Analyses

The results of the analyses of the nine metals monitored in sediments and invertebrates during this study are presented in the Appendix Tables Ia-VIIi, pp. A 1 to A 63 . These data are given in parts per million dry weight and are either the mean values and 95% confidence limits of the indicated replicates or individual values where no replicates were analyzed.

In the discussions presented below, the mean concentration values and one standard deviation of the mean values observed at dredge zone stations (SI,SO,TI,TO,DI, and DO) are compared to the mean concen-

trations observed at stations outside of the dredging area (NI,NO, EI,EO,WI,WO,and SP). These grand mean values are presented in Tables 2-6, p. 36 and pp. 48-51.

The data obtained during this study was analyzed by a "group pairing design test" to determine whether changes in metal concnetrations in sediments and invertebrates at dredge zone stations were greater than at outside stations during the dredging operations. Both dredging periods were treated as one experiment and all stations with suitable data were combined. The mean concentrations observed during or just after dredging were subtracted from the most immediate predredging values for each station. The differences observed at stations inside the dredging area were then compared with changes at the outside stations in a group comparison test. Significant _t_ ratios indicate a significant difference in the amount of change between inside and outside stations. This test is a combination of a pairing design and a group comparison test and is therefore referred to as a "group pairing design test". The results of this test are presented in Table 7A p. 52.

To gain insight into any general trends that occurred during the study period, a two-way anova without replication was performed on the mean concentration values observed in sediments, _M. balthica_, _N. succinea_, _A. milleri_, and _M. edulis_ transplants. This test compares changes observed between station and through all collections. The results of the two-way anova are presented in Table 7B p. 53.

The laboratory data for Cu, Hg, and Pb concentrations in M. balthica were subjected to a three-way anova (Model I, with replication for Hg values and without replication for Cu and Pb values) to

test primary effects, and first and second order interactions among the variables: salinity, concentration, and time. The results of this test are presented in Table 13, p. 73 .

III. Results of Metals Analyses

A. Dredge Period Collections

1. Sediments

The results of metal analyses of sediments collected at all stations during all collections in this study are presented in the Appendix Tables (Ia-Ii, p. A 1-9). The mean and one standard deviation of concentrations observed within dredge zone stations are compared with the mean concentration of values observed at stations outside of the dredge zone in Table 2, p. 36 .

The concentrations of the nine metals analyzed remained relatively constant in sediments from dredge zone and outer stations throughout the period of study. No significant differences through time or between stations were observed in Ag, Cd or Se. Changes through time and differences between stations observed in the other metals did not appear to be related to dredging activities (Table 7A, 7B).

The mean concentration of the metals Cd, Cu, Pb, and Hg in Mare Island sediments analyzed during this study are similar to the values of these metals reported by McCulloch et al. (1971), Peterson et al. (1972), Haupert (1972), Moyer and Budinger (1974), and Anonymous (1975). The metal concentrations presented in this report are less than or comparable to levels of these metals found in other parts

Table 2. The means and one standard deviation of the concentrations of nine metals in sediments collected at dredge zone stations* and stations outside of the dredging area** during the six subtidal biological collections. Values are expressed as ppm dry weight with the number of stations analyzed also indicated.

		Date / Collection					
Dredging Period			(----------	----------)	(----------	----------)	
Metals	Stations	8Oct73 I	24Oct73 II	24Nov73 IV	12Feb74 VI	28Mar74 VIII	28Apr74 IX
Ag	I*	2.8±.8 (6)	1.7±.6 (6)	2.1±1.2 (6)	3.3±1.2 (4)	2.1±.7 (4)	2.0±.6 (4)
	O	1.7±.8 (7)	2.3±.7 (7)	2.1±1.4 (7)	2.8±.0 (2)	1.9±.3 (2)	2.2±.8 (2)
As	I	12.7±2.3 (6)	12.1±2.3 (6)	12.6±2.3 (6)	11.2±1.6 (4)	14.5±1.9 (4)	9.5±.9 (4)
	O	11.2±2.3 (7)	9.5±2.7 (7)	9.3±1.9 (7)	13.2±2.6 (2)	15.1±2.1 (2)	19.2±8.0 (2)
Cd	I	1.7±.6 (6)	1.4±.5 (6)	2.4±1.3 (6)	3.0±1.0 (4)	2.0±1.1 (4)	2.4±.8 (4)
	O	1.2±.3 (7)	2.0±.6 (7)	1.7±.5 (7)	1.6±2.2 (2)	2.3±.5 (2)	2.1±.1 (2)
Cu	I	90±8 (6)	92±16 (6)	89±9 (6)	89±9 (4)	89±7 (4)	85±7 (4)
	O	77±12 (7)	78±13 (7)	82±14 (7)	87±8 (2)	78±5 (2)	101±2 (2)
Ni	I	90±8 (6)	90±13 (6)	94±9 (5)	93±15 (4)	111±11 (4)	92±4 (4)
	O	79±11 (7)	76±8 (7)	93±14 (7)	96±0 (2)	92±12 (2)	88±1 (2)
Pb	I	58±9 (6)	59±13 (6)	56±9 (6)	39±16 (4)	35±3 (4)	40±6 (4)
	O	48±6 (7)	52±10 (7)	52±8 (7)	46±1 (2)	40±5 (2)	47±4 (2)
Se	I	1.7±.6 (6)	2.6±.8 (6)	1.5±.9 (6)	2.2±.6 (4)	2.3±.6 (4)	2.3±.8 (4)
	O	2.4±.7 (7)	2.1±.7 (7)	1.5±.8 (7)	3.3±.5 (2)	1.7±.1 (2)	1.5±2.1 (2)
Zn	I	165±11 (6)	161±17 (6)	159±18 (6)	151±16 (4)	146±7 (4)	145±9 (4)
	O	140±16 (7)	143±20 (7)	147±17 (7)	140±4 (2)	138±6 (2)	162±7 (2)

* dredge zone stations: SI,SO,TI,TO,DI,DO.

** stations outside of the dredge zone: NI,NO,EI,EO,WI,WO,SP.

of San Francisco Bay and are much lower than those found in sediments considered "polluted" in other industrialized ports such as Los Angeles and Baltimore Harbors (Chen and Wang, 1974; Villa and Johnson, 1974). It is interesting that neither dredging activity nor reduced salinity and increased sediment transport significantly altered the total concentrations of the metals analyzed during this study.

2. Invertebrates

The results of the metals analyses of the benthic species *M. balthica*, *N. succinea*, *A. milleri*, and the mussels *I. demissum* and *M. edulis* are discussed in this section. The mean concentration of the nine metals, the 95% confidence limits and number of replicates of these species at each station during all collections are presented in the Appendix Tables IIa -VIIi, pp. A 10 to A 63 .

The mean concentration values and one standard deviation of the mean concentration of metals in the three benthic species and *M. edulis* from dredge zone and outer stations are presented in Tables 3-6, pp. 48 to 51 . The data are discussed by metal in relation to stations within and outside of the dredge zone during the two dredging periods.

Silver

Silver concentrations remained near or below the detection limits of our instrument (< 1.0ppm) in *N. succinea*, *A. milleri*, *I. demissum* and both native and trasplanted *M. edulis*. The mean concentration of Ag remained below 2.0 ppm in *N. succinea* and below 1.0 ppm in *A. milleri*, *I. demissum* and *M. edulis*. No significant differences were observed between dredge zone and outer stations in any of these species (Tables 4-6 and Va, p. A 37).

Significant changes were seen in M. balthica after both dredging periods. However, these changes were not significantly greater at stations within the dredge zone than at those outside of the dredging area. There was a gradual increase with time from approximately 2.0 ppm to 3.0 ppm at all stations suggesting that these increases were a result of natural phenomena (Tables 3, 7A and 7B, pp. 48 , 52 and 53).

Arsenic

The mean concentration of As in M. balthica, I. demissum and native and transplanted M. edulis did not change significantly with time and no correlations were observed with either dredging or rainfall period (Table 7B). Arsenic concentrations in these species were approximately: M. balthica - 10 ppm; I. demissum and M. edulis - 7 ppm.

Significant increases were observed in the As concentrations in N. succinea and A. milleri but these increases were observed either before dredging began (N. succinea) or occurred equally at both dredge zone and outer stations (A. milleri). The observed increases were not correlated with either dredging or rainfall periods (Tables 7A and 7B). Mean As concentrations ranged between 4-5 ppm in both N. succinea and A. milleri.

Cadmium

No significant changes were observed in the Cd concentrations of M. balthica, A. milleri, I. demissum or transplanted M. edulis

(Tables 3, 5, 6 and Vc, p. A 39). Cadmium concentrations were approximately 15 ppm in I. demissum, 10 ppm in transplanted M. edulis, and 2 ppm in both M. balthica and A. milleri.

A significant increase in Cd concentrations was observed in N. succinea at both dredge zone and outer stations after the second dredge period (Table 7B). A similar increase was not observed during the first dredge period. Observed changes were not significantly different between inside and outside stations during either dredge period (Table 7A).

Concentrations of Cd in native M. edulis increased from 10 ppm to 20 ppm with time at both the dredge zone and outer station, but this increase was not correlated with either dredging or rainfall period (Table 6).

Cadmium concentrations in transplanted mussels were slightly higher than those in Tomales Bay samples suggesting an accumulation of Cd by these mussels. It is interesting that Cd levels in transplanted animals did not reach levels observed in native mussels during this study. Studies conducted by Koehn and Mitton (1972) have shown that M. edulis and I. demissum from different geographic locations exhibit parallel patterns of genetic variation at homologous loci. This suggests that differing selection pressures in different areas would produce populations with different genetic structures. It is possible that Tomales Bay mussels are genetically different than native M. edulis and that Cd uptake and accumulation,

if it occurs, is much slower in the transplanted mussels.

Mean Cd concentrations did not exceed 5 ppm in N. succinea during this study and the range of Cd values was similar to those reported for other polychaete species (0.1 - 3.5 ppm; Bryan and Hummerstone, 1973). Concentrations of Cd in I. demissum were higher than those reported for a closely related species, Modiolus modiolus, from the Atlantic coast (6.0 ppm; Segar et al., 1971), and Cd levels in M. balthica were within the range of values (1-10 ppm) observed in other clams (Shuster and Pringle, 1968; Graham, 1972). The Cd concentrations observed in native and transplanted M. edulis were within the range of Cd values reported for this species (2-40 ppm; Mullin and Riley, 1956; Brooks and Rumsby, 1965; Segar et al., 1971; Graham, 1972; and Topping, 1972).

Copper

No significant differences in Cu concentrations were observed through time or between stations in A. milleri, I. demissum or transplanted M. edulis and no significant differences in Cu levels in native M. edulis were related to either dredging or rainfall periods (Table 7A and 7B).

Significant increases in the mean concentrations of Cu with time were observed in M. balthica and N. succinea at both dredge zone and outside stations (Table 7A, B). Copper concentrations in M. balthica increased from 30 ppm before the first dredging period to 90 ppm after the second dredging period. Concentrations of Cu in

N. succinea increased by a factor of two (25-45 ppm) during the period of study. Neither of the above increases were related to either of the two dredging-rainfall periods (Table 7A and B).

The average concentration of Cu in I. demissum was 20 ppm which is similar to the closely related M. modiolus (27 ppm; Segar et al., 1971). A. milleri had an average of 60 ppm Cu and Cu values in N. succinea (19-46 ppm) were low compared to the range reported by Phelps (1967) and Bryan and Hummerstone (1971; 1973) who observed Cu levels from 20-2000 ppm in Nepthys incisa, Nereis diversicolor, and another Nereis sp. Copper concentrations appeared to be high in M. balthica in relation to the reported range of Cu in other estuarine clams such as: Tapes japonica (as semidecussata) (19 ppm) and Protothaca staminea (8 ppm) collected in San Francisco Bay (Graham, 1972) or in Mya arenaria (23 ppm) collected along the Atlantic coast (Shuster and Pringle, 1968).

Copper levels in Tomales Bay mussels fluctuated slightly from 5.5 - 9.0 ppm while native M. edulis averaged 12 ppm through time except during one collection. The range of Cu values at all stations through time was 5-30 ppm, which is similar (5-36 ppm) to the range of Cu values reported by other workers for this species (Brooks and Rumsby, 1965; and Graham, 1972).

Mercury

Mercury concentrations were not significantly different through time in I. demissum at any station. Concentrations of Hg

increased with time in native _M. edulis_ at stations both inside and outside of the dredge zone during the first dredge period and continued to increase at the stations outside of the dredging area through the final collection 28 April 1974 (Table 6). Mercury levels in transplanted mussels and in Tomales Bay mussels increased slightly after the first dredging-rainfall period and then decreased with time. These changes were not correlated with either dredging or rainfall and were different than those observed in native _M. edulis_, further suggesting possible genetic or physiological differences in these two populations. The mean concentration range (0.17 to 0.74 ppm) was low compared to Hg values reported in _M. edulis_ from other locations which range from 1-9 ppm (Segar _et al._, 1971; Bertine and Goldberg, 1972).

Significant increases in Hg concentrations were observed in _M. balthica_ and _N. succinea_ after both dredging periods (Table 7B). These increases were not significantly different at stations within the dredge zone than at stations outside of the dredging area and hence cannot be considered a result of dredging activity (Table 7A).

A significant difference in Hg levels with time was observed in _A. milleri_ at all stations after the first dredge period (Table 7B). Increases in Hg observed at stations within the dredge zone were not significantly greater than those observed outside of the dredging area (Table 7A).

Nickel

No significant differences with time or between stations were

observed in *I. demissum*, *N. succinea* or native and transplanted *M. edulis* (Table 7B). Nickel values ranged between 1-4 ppm in *I. demissum* and between 8-15 ppm in *N. succinea*. Mean Ni concentrations were 2-3 times higher in native *M. edulis* (10-15 ppm) than in Tomales Bay mussels which averaged between 4-8 ppm. Mussels transplanted to dredge zone stations ranged from 6-27 ppm Ni and mussels at outer stations ranged from 5-18 ppm Ni.

Highly significant differences with time were found in the Ni levels observed in *M. balthica* and *A. milleri* (Table 7B). The Ni concentrations decreased significantly prior to the second pre-dredging collection in both *M. balthica* and *A. milleri* and then significantly increased in both species after the first dredging period (Tables 3, 5, and 7B).

These changes were equivalent at both dredge zone and outer stations and do not appear to be related to dredging activity (Table 7A). Nickel concentrations ranged from 7-15 ppm in both *M. balthica* and *A. milleri* during this study.

Lead

Neanthes succinea showed no significant increase in the mean concentration of Pb (2.5 ppm) with time and no significant differences were observed between stations (Table 7A and B). Lead levels in *N. succinea* were comparable to those reported for other similar species which ranged from 1-6 ppm Pb (Bryan and Hummerstone, 1971).

Lead values remained low (1-2 ppm) in Tomales Bay mussels and

mussels transplanted to Mare Island Strait and no significant differences were observed with time or between stations in this species (Table 7B). An increase in the mean Pb concentrations in native *M. edulis* was observed during and after the first dredging-rainfall period, but owing to the wide variance associated with these values and the absence of a similar increase during the second dredging period, no comparisons were made (Table 6). The Pb levels in Mare Island native and transplanted mussels were relatively low, 1-7 ppm, as compared to the range of Pb values (0.1-48 ppm) reported by a number of other workers (Cheftel *et al.*, 1949; Costa and Molina, 1957; Brooks and Rumsby, 1965; Segar *et al.*, 1971; Graham, 1972; Nickless *et al.*, 1972; Schulz-Baldes, 1972).

A highly significant difference in Pb levels in *I. demissum* was observed between stations (Table 7B). Mussels at station STM had Pb values nearly twice as high (5 ppm) as at the other two stations before the first dredging period (Table Vg, p. A44). The Pb concentrations remained unchanged at all stations through time and the higher values at station STM appear to be unrelated to dredging activity. Pb levels in *I. demissum* appear to be low when compared to the levels (33 ppm) reported by Segar *et al.* (1971) for *M. modiolus*.

Lead concentrations in *M. balthica* increased significantly after the two dredge periods from 2 ppm before the first dredging period to 5 ppm after the second dredge period. This gradual increase with time was observed at both dredge zone and outer station

and no significant differences were observed between these station sites (Tables 5 and 7B).

The Pb values observed in _M. balthica_ during this study were similar to levels reported for other clams in San Francisco Bay and Atlantic coast estuaries. The range of Pb concentrations in other clams was from 2-5 ppm (Shuster and Pringle, 1968; Graham, 1972).

A significant decrease in Pb levels before the first dredging period followed by a significant increase after this period was observed in _A. milleri_ at both dredge zone and outer stations (Table 7B). The amount of increase at stations within the dredge zone was not significantly greater than increases observed at outer stations (Table 7A). Population data indicated that environmental factors were exerting strong pressure on this species during the third collection. Since no specimens were collected at stations NI and NO, it appears that pressure was greatest in the upper part of MIS where the greatest population declines and highest metal concentrations were observed (Table 5, Fig.12 , p.69).

Selenium

Selenium concentrations were not significantly different through time or between stations in _I. demissum_, native and transplanted _M. edulis_ or in _M. balthica_. The mean concentration of Se in each of these three species was approximately 5 ppm Se.

A significant decrease in Se levels was observed in _A. milleri_ after the first dredging period at both dredge zone and outer

stations (Table 7B). The decrease was not significantly different between outside stations and those within the dredge zone (Tables 5 and 7A).

Levels of Se were significantly different through time in N. succinea (Table 7B). A significant increase was observed after the second dredge period. However, a similar increase was seen before the first dredging period and no significant difference between dredge zone and outer stations were observed (Table 7A). Selenium levels averaged 2.5 ppm in A. milleri and 6.5 ppm in N. succinea.

Zinc

Mean concentrations of Zn were not significantly different through time or between stations in N. succinea and M. edulis native to MIS or transplanted to either dredge zone or outer stations (Table 7B). The levels of Zn were slightly higher in native and transplanted mussels than in Tomales Bay samples suggesting slight accumulation of this element by transplanted animals.

Zinc concentrations in N. succinea averaged approximately 300 ppm and Phelps (1967) and Bryan and Hummerstone (1971) found similar values (25-200 ppm) in other species of polychaetes. Mean Zn concentrations in native and transplanted M. edulis ranged from 100-300 ppm at all stations and were well within the reported range (40-3000 ppm) of Zn values in this species (Brooks and Rumsby, 1965; Macchi, 1965; Bertine and Goldberg, 1972; Graham, 1972; and Ireland, 1973).

Levels of Zn in I. demissum at station STM were significantly greater than at the two outer stations NVM and OWM (Table Vi and 7B). No significant differences through time, however, were observed at any of these three stations and the higher Zn levels at station STM are unrelated to dredging activities. Concentrations of Zn reported in the similar species Modiolus modiolus from the Atlantic Coast were much higher (425 ppm) than observed in I. demissum (75 ppm) during this study (Segar et al., 1971).

Significant differences in Zn concentrations through time were observed in M. balthica and A. milleri (Table 7B). Mean Zn concentrations in M. balthica followed the same trend as Cu values; levels of Zn increased significantly by a factor of two (300 ppm to 700 ppm) during the study period (Table 3). There was no significant difference between dredge zone and outer stations and no correlation with dredging-rainfall periods (Table 7A). Zinc levels observed in M. balthica were an order of magnitude greater than levels observed in other clams from San Francisco Bay, the Atlantic Coast and Japan which ranged from 11-76 ppm (Ichikawa and Ohno, 1965; Shuster and Pringle, 1968; Graham, 1972).

Concentrations of Zn decreased significantly in A. milleri before the first dredging period and significantly increased after this period. These changes occurred at stations within the dredge zone and at outer stations and no significant difference in Zn levels were observed between these two station sets (Tables 5 and 7A).

Table 3. The grand means and one standard deviation of the mean concentrations of nine metals in M. balthica collected at dredge zone stations* and at stations outside of the immediate dredging area** during the six subtidal biological collections. Values are expressed as ppm dry weight with the number of stations analyzed also indicated.

Dredging Period		Date / Collection					
			(----------	----------)	(----------	----------)	
Metals	Stations	8Oct73 I	22Oct73 II	22Nov73 III	11Feb74 IV	28Mar74 V	19Apr74 VI
Ag	I	1.2±.2 (6)	1.0±.3 (6)	2.2±.6 (6)	2.3±.2 (4)	3.5±.8 (4)	4.4±1.4 (4)
	O	1.5±.5 (7)	1.1±.3 (7)	2.0±.6 (7)	1.9±1.0 (2)	3.2±.4 (2)	2.8±1.2 (2)
As	I	10.8±1.9 (6)	11.6±2.7 (6)	11.6±2.0 (6)	8.9±1.9 (4)	10.9±2.3 (4)	10.1±1.3 (4)
	O	11.1±2.4 (7)	12.2±4.3 (7)	11.5±2.3 (7)	9.4±2.4 (2)	11.6±1.9 (2)	12.4±4.4 (2)
Cd	I	0.7±.2 (6)	1.2±.7 (6)	1.0±.4 (6)	1.1±.4 (4)	1.7±.7 (4)	1.9±.5 (4)
	O	1.2±.6 (7)	1.2±1.0 (7)	0.8±.2 (7)	0.7±.1 (2)	1.5±.1 (2)	1.0±.9 (2)
Cu	I	45±9 (6)	29±16 (6)	66±6 (6)	70±10 (4)	87±31 (4)	95±23 (4)
	O	37±11 (7)	30±10 (7)	64±12 (7)	81±30 (2)	85±21 (2)	89±18 (2)
Hg	I	.20±.02 (6)	.19±.03 (6)	.34±.06 (6)	.30±.06 (4)	.39±.06 (4)	.38±.10 (4)
	O	.21±.04 (7)	.20±.02 (7)	.35±.06 (7)	.29±.06 (2)	.38±.08 (2)	.37±.12 (2)
Ni	I	7.[illegible].9 (6)	2.4±.7 (6)	15.0±6.5 (6)	8.8±2.1 (4)	15.8±14.1 (4)	9.5±3.0 (4)
	O	13.4±12.6 (7)	3.2±2.3 (7)	5.8±2.3 (7)	1.9±.4 (2)	1.8±.4 (2)	3.4±3.4 (2)
Pb	I	2.2±.6 (6)	1.9±1.5 (6)	6.7±4.2 (6)	2.5±.9 (4)	5.0±4.0 (4)	2.7±1.2 (4)
	O	1.7±.9 (7)	2.0±2.3 (7)	5.8±2.3 (7)	1.9±.4 (2)	1.8±.4 (2)	3.4±3.4 (2)
Se	I	5.5±.6 (6)	5.4±.9 (6)	5.2±.6 (6)	5.0±.3 (4)	5.9±1.3 (4)	5.7±.8 (4)
	O	5.2±.6 (7)	5.2±.8 (7)	4.8±.4 (7)	4.5±.7 (2)	6.7±.4 (2)	5.6±.4 (2)
Zn	I	318±44 (6)	360±102 (6)	458±107 (6)	442±91 (4)	560±88 (4)	729±244 (4)
	O	283±45 (7)	304±103 (7)	357±86 (7)	382±62 (2)	653±27 (2)	689±23 (2)

* dredge zone stations: SI,SO,TI,TO,DI,DO.

** stations outside of dredge zone: NI,NO,EI,EO,WI,WO,SP.

Table 4. The grand means and one standard deviation of the mean concentrations of nine metals in N. succinea collected at dredge zone stations* and at stations outside of the immediate dredging area** during the six subtidal biological collections. Values are expressed as ppm dry weight with the number of stations analyzed also indicated.

		Date / Collection					
Dredging Period			(----------	----------)	(----------	----------)	
		8Oct73	22Oct73	22Nov73	11Feb74	28Mar74	19Apr74
Metals	Stations	I	II	III	IV	V	VI
Ag	I*	1.0±.3	1.2±.4	1.3±.7	0.8±.1	1.9±.3	1.1±.6
		(6)	(6)	(6)	(4)	(4)	(4)
	O**	0.8±.3	0.9±.3	1.1±.7	0.9±.2	1.7±.4	1.5±.9
		(7)	(7)	(7)	(2)	(2)	(2)
As	I	5.6±1.0	7.6±3.1	4.8±1.4	4.3±.9	4.9±1.8	5.0±.8
		(6)	(6)	(6)	(4)	(4)	(4)
	O	5.9±1.5	5.8±1.2	4.9±.8	5.8±.3	5.8±.3	5.8±.8
		(7)	(7)	(7)	(2)	(2)	(2)
Cd	I	1.5±.5	1.5±.6	1.6±.6	1.9±.9	3.5±1.6	1.7±1.0
		(6)	(6)	(6)	(4)	(4)	(4)
	O	2.1±.6	1.6±.5	1.8±1.1	1.7±.3	3.3±.5	1.6±.1
		(7)	(7)	(7)	(2)	(2)	(2)
Cu	I	27±8	32±7	28±5	31±6	44±11	43±10
		(6)	(6)	(6)	(4)	(4)	(4)
	O	22±5	20±3	24±4	37±15	39±4	47±16
		(7)	(7)	(7)	(2)	(2)	(2)
Hg	I	.17±.04	.19±.04	.20±.03	.19±.04	.31±.14	.25±.07
		(6)	(6)	(6)	(4)	(4)	(4)
	O	.14±.05	.16±.02	.22±.03	.20±.03	.27±.01	.23± 0
		(7)	(7)	(7)	(2)	(2)	(2)
Ni	I	16±7	13±5	9±4	9±3	9±4	9±1
		(6)	(6)	(6)	(4)	(4)	(4)
	O	11±8	8±4	14±5	10±2	8±1	10±4
		(7)	(7)	(7)	(2)	(2)	(2)
Pb	I	4.2±3.2	4.5±1.7	3.4±1.6	1.9±.4	3.7±1.5	3.8±2.2
		(6)	(6)	(6)	(4)	(4)	(4)
	O	2.7±1.0	2.1±.6	3.5±.7	2.3±1.4	1.7±.4	2.9±1.0
		(7)	(7)	(7)	(2)	(2)	(2)
Se	I	6.4±1.1	8.4±1.9	6.1±.8	6.2±.6	7.2±1.5	6.5±.6
		(6)	(6)	(6)	(4)	(4)	(4)
	O	5.7±1.1	6.9±.9	5.8±.9	6.4±.9	7.1±1.1	6.2±.8
		(7)	(7)	(7)	(2)	(2)	(2)
Zn	I	296±108	356±106	331±113	300±70	522±298	365±128
		(6)	(6)	(6)	(4)	(4)	(4)
	O	290±130	351±111	383±179	326±62	418±105	268±35
		(7)	(7)	(7)	(2)	(2)	(2)

* dredge zone stations: SI,SO,TI,TO,DI,DO.

**stations outside of dredge zone:NI,NO,EI,EO,WI,WO,SP.

Table 5. The grand means and one standard deviation of the mean concentrations of nine metals in A. *milleri* collected at dredge zone stations* and at stations outside of the immediate dredging area** during the first three subtidal biological collections. Values are expressed as ppm dry weight with the number of stations analyzed also indicated.

Dredging Period		Date / Collection		(------------------------------)
Metals	Stations	8Oct73 I	22Oct73 II	22Nov73 III
Ag	I*	0.9±.2 (6)	0.9±.3 (6)	1.1±.2 (6)
	O**	0.8±.2 (7)	0.9±.1 (7)	1.2±.2 (7)
As	I	4.3±.4 (6)	3.8±.3 (6)	5.2±.7 (6)
	O	4.0±1.2 (7)	3.9±.2 (7)	5.7±.7 (7)
Cd	I	2.6±.5 (6)	2.4±.4 (6)	2.0±.8 (6)
	O	2.3±.4 (7)	2.4±.4 (7)	2.3±.3 (7)
Cu	I	67±19 (6)	72±3 (6)	55±10 (6)
	O	51±13 (7)	67±7 (7)	61±10 (7)
Hg	I	.10±.01 (6)	.14±.09 (6)	.35±.22 (6)
	O	.09±.01 (7)	.13±.05 (7)	.18±.03 (7)
Ni	I	10.1±1.3 (6)	4.2±.6 (6)	16.2±3.5 (6)
	O	7.3±2.3 (7)	5.8±.9 (7)	16.8±3.6 (7)
Pb	I	2.7±1.5 (6)	1.5±.3 (6)	8.2±6.8 (6)
	O	2.3±2.5 (7)	1.4± 0 (7)	3.3±1.8 (7)
Se	I	2.7±.3 (6)	2.6±.1 (6)	2.1±.3 (6)
	O	2.7±.3 (7)	2.6±.2 (7)	2.3±.2 (7)
Zn	I	74±8 (6)	63±1 (6)	75±11 (6)
	O	66±4 (7)	63±2 (7)	72±4 (7)

* dredge zone stations: SI,SO,TI,TO,DI,and DO.
**stations outside of dredge zone: NI,NO,EI,EO,WI,WO, and SP.

Table 6. A comparison of the grand means and means of nine metals in M. edulis collected at Tomales Bay and transplanted to dredge zone stations* and to stations outside of the dredging area**, and mussels native to Mare Island Strait. Values are expressed as ppm dry weight and the number of stations tested is also indicated.

		Date / Collection								
Dredging Period		(-------------	-------------)		(------------------		-------------------)			
Metals	Stations	26Oct73 I	10Nov73 II	23Nov73 III	21Dec73 IV	12Feb74 V	13Mar74 VI	29Mar74 VII	18Apr74 VIII	29May74 IX
Ag	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	-	-	N.D.
As	TB[1]	5.6	6.1	6.3	6.6	8.3	7.1	-	-	6.6
	N[2]	6.5±.6 (2)	8.3±1.3 (2)	7.2±.2 (2)	7.4±.6 (2)	7.2	9.5	-	11.1	-
	I*	6.7±.8 (3)	6.7±.4 (3)	6.9±.5 (3)	6.4±.2 (3)	6.6±.8 (2)	9.0±1.3 (2)	-	-	-
	O**	6.4	6.1	7.1	6.4	6.6±.8 (2)	7.3	8.0	7.5	-
Cd	TB	2.2	2.7	3.5	4.6	1.7	2.6	-	-	2.0
	N	10.9±1.6 (2)	12.3±2.9 (2)	7.7±4.5 (2)	7.9±4.2 (2)	19.3	25.4	20.8	25.9	-
	I	3.3±.3 (3)	3.7±.4 (3)	4.2±.6 (3)	.8±1.4 (3)	4.2±2.4 (2)	3.2±.9 (2)	-	-	-
	O	3.0	4.0	4.0	9.9	5.0±2.7 (2)	4.1	5.0	5.6	-
Cu	TB	5.5	8.2	8.3	7.1	9.0	6.3	-	-	5.5
	N	10.1±.8 (2)	12.8±.1 (2)	16.5±4.3 (2)	14.6±3.5 (2)	10.9	30.7	-	16.5	-
	I	11.3±1.0 (3)	11.5±1.5 (3)	11.2±.7 (3)	9.7±1.1 (3)	8.1±2.9 (2)	22.8±1.7 (2)	-	-	-
	O	14.0	10.4	10.3	10.5	10.9±6.4 (2)	9.7	10.2	18.2	-
Hg	TB	.17	.20	.28	.33	.41	.31	-	-	.26
	N	.25±.02 (2)	.37±.07 (2)	.42±.01 (2)	.40±.07 (2)	.45	.56	.66	.74	-
	I	.28±.02 (3)	.30±.0 (3)	.37±.06 (3)	.44±.05 (3)	.35±.10 (2)	.29±.0. (2)	-	-	-
	O	.22	.28	.43	.51	.40±.14 (2)	.40	.45	.50	-
Ni	TB	3.8	5.1	5.4	6.0	7.9	5.1	-	-	5.2
	N	14.3±10.5 (2)	9.2±1.9 (2)	13.5±5.0 (2)	13.0±5.2 (2)	9.2	11.9	-	16.6	-
	I	10.6±3.9 (3)	6.9±1.1 (3)	8.5±1.6 (3)	10.6±2.2 (3)	6.4±1.5 (2)	27.0±3.0 (2)	-	-	-
	O	5.7	5.7	8.1	10.9	11.3±9.1 (2)	7.8	8.1	18.5	-
Pb	TB	1.1	3.1	1.0	1.0	1.0	1.0	-	-	-
	N	2.0±.3 (2)	4.8±3.4 (2)	7.1±6.7 (2)	5.7±4.6 (2)	1.9	2.4	-	2.9	-
	I	1.5±.4 (3)	2.6±1.2 (3)	1.3±.3 (3)	1.8±.9 (3)	1.1±.1 (2)	4.6±1.3 (2)	-	-	-
	O	1.3	1.2	1.2	1.3	2.2±.6 (2)	2.3±1.8 (2)	7.7	2.3	-
Se	TB	4.6	4.6	5.4	5.0	2.9	3.4	-	-	2.8
	N	7.3±1.8 (2)	8.5±.4 (2)	6.1±.2 (2)	5.7±.4 (2)	5.0	6.7	-	5.2	-
	I	4.8±.6 (3)	5.6±1.0 (3)	5.8±.4 (3)	4.2±.1 (3)	4.2±.8 (2)	2.6±.2 (2)	-	-	-
	O	4.2	4.3	5.1	4.3	4.2±.5 (2)	4.9	5.9	3.9	-
Zn	TB	111	145	135	139	166	151	-	-	111
	N	170±28 (2)	216±33 (2)	226±98 (2)	176±14 (2)	210	249	-	239	-
	I	182±19 (3)	164±43 (3)	196±44 (3)	235±46 (3)	177±107 (2)	233±23 (2)	-	-	-
	O	178	160	236	231	271±107 (2)	174	142	284	-

1. TB= M. edulis collected at Tomales Bay at beginning of transplant experiment and returned to Tomales Bay in Nytex bags as control samples.
2. N= M. edulis native to MIS collected from stations STP and OWP.
* I= M. edulis transplanted to stations within the dredge zone; ST,SO,T,TO,and D.
** O= M. edulis transplanted to stations outside of the dredge zone;NO,WO, and SP.

Table 7A. Results of group pairing design test of the changes observed during dredging. Changes observed in stations outside of the dredge area are compared to changes observed within the dredge zone. Collections used in this comparison are listed under each of the respective sample types. Values for $(\bar{X}_{d2}-\bar{X}_{d1})$ are the amount of difference, in parts per million dry weight, between changes observed.

Sample/Collection		Ag	As	Cd	Cu	Hg	Ni	Pb	Se	Zn
Sediments: Coll. II+ III; VI+VIII.	t	0.66	0.68	0.63	0.71	0.01	0.36	0.48	0.12	1.41
	df	17	17	17	17	17	17	17	17	17
	$(\bar{X}_{d2}-\bar{X}_{d1})$	0.32	1.37	0.35	4.07	0.03	2.51	2.00	0.06	8.39
Ampelisca milleri: Coll. II+III.	t	0.63	0.80	0.57	1.57	1.02	0.32	1.57	1.27	0.60
	df	8	8	8	8	9	8	8	8	8
	$(\bar{X}_{d2}-\bar{X}_{d1})$	0.08	0.28	0.18	10.36	0.11	0.70	4.92	0.16	3.02
Neanthes succinea: Coll. II+III; IV+V.	t	0.18	0.77	0.47	0.11	0.24	2.35*	0.86	0.35	0.39
	df	16	17	16	17	17	17	17	17	17
	$(\bar{X}_{d2}-\bar{X}_{d1})$	0.67	0.75	0.22	0.44	0.01	5.70	0.83	0.33	27.91
Macoma balthica: Coll. II+III; IV+V.	t	0.56	0.96	0.55	0.04	0.43	0.21	0.72	0.20	0.11
	df	16	17	16	17	17	17	17	17	17
	$(\bar{X}_{d2}-\bar{X}_{d1})$	0.17	0.90	0.24	0.33	0.01	0.85	1.05	0.12	4.77
Mytilus edulis Trans.: Coll. II+III.	t	.0	0.52	5.09	0.31	2.92	1.30	0.86	0.86	0.56
	df	2	2	2	2	2	2	2	2	2
	$(\bar{X}_{d2}-\bar{X}_{d1})$	0	0.55	1.05	0.90	0.43	3.75	0.90	1.15	12.50

*Significant at p=.05 level.

$t_{.05(2)}=4.30$ $t_{.05(8)}=2.31$ $t_{.05(9)}=2.26$ $t_{.05(16)}=2.12$ $t_{.05(17)}=2.11$

Table 7B. Results of a two-way analysis of variance, without replication, of the results of metal analyses of sediments and invertebrates collected at all stations during the first dredging period. The resultant F ratios are presented for comparisons through time and between stations. The collections and stations tested by two-way analysis of variance are listed under each sample type. The ( ) values are degrees of freedom.

Sample/Collection	(df)	Ag	As	Cd	Cu	Hg	Ni	Pb	Se	Zn
Sediments: Coll. I-IV, All stations.	Coll. (3)	0.02	1.08	3.30'	0.52	1.06"	7.29"	1.64	2.49	0.38
	Stat. (12)	1.46	1.80	1.85	10.07"	9.34"	6.70"	4.93"	0.81	7.26"
	(error) (36)									
Ampelisca milleri: Coll. I-III, Excludes stations NI, NO, SO.	Coll. (2)	N.D.	32.79"	0.39	2.88	4.44'	46.69"	6.90"	13.68"	10.30"
	Stat. (9)		3.16'	1.15	0.74	0.75	0.48	1.71	2.01	1.91
	(error) (18)									
Macoma balthica: Coll. I-III, All stations.	Coll. (2)	25.90"	0.86	1.25	61.63"	93.1[illegible]"	17.17"	22.62"	1.46	8.09"
	Stat. (12)	1.94	3.49"	1.48	2.32'	3.[illegible]	2.38'	2.07	2.89'	3.13"
	(error) (24)									
Macoma balthica: All collections, Stations NO, SI, SO, DI, DO, SP.	Coll. (5)	15.83"	2.89'	4.05"	19.63"	16.84"	2.22	2.79'	3.27'	11.11"
	Stat. (5)	2.05	10.34"	3.20'	4.18"	3.49'	2.62'	4.09"	3.65'	2.02
	(error) (25)									
Neanthes succinea: Coll. I-III, All stations.	Coll. (2)	N.D.	4.57'	0.65	0.30	9.33"	0.99	0.10	8.93"	2.63
	Stat. (12)		1.93	1.92	4.72"	2.56'	0.99	1.80	1.56	4.86"
	(error) (24)									
Neanthes succinea: All collections, Stations NO, SI, SO, DI, DO, SP.	Coll. (5)	N.D.	0.41	8.26"	8.24"	9.02"	1.76	1.42	3.43'	5.65"
	Stat. (5)		3.18'	6.39"	5.08"	8.40"	0.97	3.48'	2.54	11.36"
	(error) (25)									
Ischalium domissum: Collections I-VII, All stations.	Coll. (6)	N.D.	1.15	1.15	4.88"	0.98	3.04'	0.32	2.01	1.52
	Stat. (2)		2.31	0.15	2.49	8.39"	2.33	32.87"	2.15	5.53'
	(error) (12)									
Mytilus edulis: Transplants, Coll. I-IV, Stations ST, T, D, SP.	Coll. (3)	N.D.	1.04	1.08	2.14	18.91"	2.45	2.49	3.96'	3.81
	Stat. (3)		0.78	1.02	1.43	1.45	1.72	4.22"	0.90	1.60
	(error) (9)									

* (df)=4
' Significant at p=.05
" Significant at p=.01

		(degrees of freedom) (df)											
		(2,12)	(2,18)	(2,20)	(2,24)	(3,9)	(3,36)	(5,25)	(6,12)	(9,18)	(10,20)	(12,24)	(12,36)
F ratios significant at	.05	3.9	3.6	3.5	3.4	3.9	2.8	2.6	3.0	2.5	2.4	2.2	2.0
	.01	6.9	6.0	5.9	5.6	7.0	4.4	3.9	4.8	3.7	3.4	3.0	2.7

Levels of Zn in A. milleri averaged approximately 70 ppm.

3. Reverse Transplants

The mean concentrations of the nine test metals in M. edulis collected from Selby Pier, Carquinez Straits and transplanted to Tomales Bay are compared with metal concentrations in Selby Pier and Tomales Bay baseline samples in Table 8, p. 55. The results are discussed by individual metals or by metals that behaved in a similar fashion in relation to the rate of desorption of these metals.

The half-time or amount of time required to desorb half the initial excess concentration of each of the respective test metals in Selby Pier mussels transplanted to Tomales Bay was determined by subtracting the concentration of each element in Tomales Bay baseline mussels from the concentration of the same element in Selby Pier baseline and transplanted mussels. The concentrations of the test metals remained constant in Tomales Bay baseline samples and were assumed to be steady state concentrations. The half-times of metals in Selby transplants were based on the time necessary to desorb one half the excess concentration of a particular element above this steady state. The excess concentrations are plotted on a semi-log graph (Fig. 8 p. 58) as a function of time. This treatment assumes the desorption rate to be exponential. Previous studies of trace metal desorption have shown most elements are released in an exponential manner (Young and Folsom, 1967; Keckes et al., 1968; Bryan and Hummerstone, 1973).

This experiment, although including a minimum of observations

TABLE 8. *Mytilus edulis* reverse transplant, Selby Pier, Carquinez Straits to Tomales Bay. Arithmetic mean values and 95% confidence limits expressed as ppm dry weight.

Element		As	Ag	Cd	Cu	Hg	Ni	Pb	Se	Zn
Station	Date									
Selby Pier I*	2 May 74	9.4 (8.3-9.4) 7	<0.8 --- 9	34.4 (23.6-45.2) 9	23.6 (21.6-25.6) 7	.686 (.592-.781) 7	14.1 (12.2-16.0) 7	10.4 (7.2-13.6) 7	4.5 (4.0-5.0) 7	174 (142-206) 7
Selby Pier II (at Tomales Bay)	29 May 74	8.2 (7.5-8.9) 9	<0.8 --- 9	19.3 (14.4-24.1) 9	8.0 (7.5-8.6) 9	.290 (.265-.312) 9	7.3 (6.3-8.3) 9	2.3 (1.3-3.4) 9	4.5 (4.0-4.9) 9	99.1 (74.7-124) 9
TB-5 IX** (Tomales Bay Control)	29 May 74	6.6 (5.8-7.3) 8	<0.9 --- 5	2.0 (1.5-2.5) 5	5.5 (4.7-6.2) 8	.256 (.219-.292) 10	5.2 (4.6-5.8) 8	0.4 (0.0-0.9) 8	2.8 (2.5-3.1) 8	111 (55.6-166) 8

* *Mytilus edulis* baseline samples used to compare with transplanted Selby Pier samples.

** Tomales Bay control used to compare ambient levels at Marconi Cove.

and ignoring the possible effects of salinity, provides a relative estimate of desorption rates of the eight metals tested.

Silver

The concentration of Ag was below the detection limit of our instrument (<1.0 ppm) in all samples and no comparisons can be made. Silver does not appear to be concentrated by *M. edulis* at these sample locations.

Arsenic

The mean As concentration was higher (9.4 ppm) in Selby Pier baseline mussels than in Tomales Bay baseline samples (6.6 ppm) at the beginning of the desorption study and decreased slightly (8.2 ppm) over the study period. The half-time of As desorption in Selby Pier transplants was calculated to be 32 days.

Cadmium

Cadmium concentrations in Selby Pier baseline mussels were 17 times higher (34 ppm) than Tomales Bay baseline samples (2 ppm) and decreased to 19.3 ppm in 27 days. The half time of this element was estimated to be 29 days.

Copper

The mean Cu concentration in Selby Pier baseline mussels was approximately 5 times (23.6 ppm) higher than in Tomales Bay baseline samples (5.5 ppm) and desorbed to a concentration of 8.0 ppm over the test period. The estimated half-time of Cu was 9 days.

Mercury

Concentrations of Hg in Selby Pier baseline samples were almost 3 times (0.69 ppm) as high as Tomales baseline mussels (0.26 ppm). Mercury concentrations decreased in Selby transplants to 0.29 with a short estimated half-time of 7 days.

Nickel

Mean values of Ni in Selby baseline mussels were also almost 3 times higher (14.0 ppm) than those observed in Tomales Bay mussels (5.5 ppm). The concentration of Ni decreased to 7.3 ppm with an estimated half-time of 13 days.

Lead

Concentrations of Pb in Selby Pier mussels averaged 10.4 ppm and were 25 times greater than Pb concentrations in Tomales Bay mussels which averaged 0.4 ppm. Desportion of Pb from Selby Pier transplants resulted in a concentration of 2.3 ppm after 27 days. The calculated half-time of this element was 11 days.

Selenium

The concentration of Se in transplanted and baseline *M. edulis* from Selby Pier were equal (4.5 ppm), with apparently no desorption occurring in 27 days. The mean concentration in Tomales Bay baseline mussels was 2.8 ppm and the half-time of Se was estimated to be greater than 50 days.

Zinc

Desorption of Zn occurred more rapidly than any of the other elements tested. Zinc concentrations in Selby transplants fell from

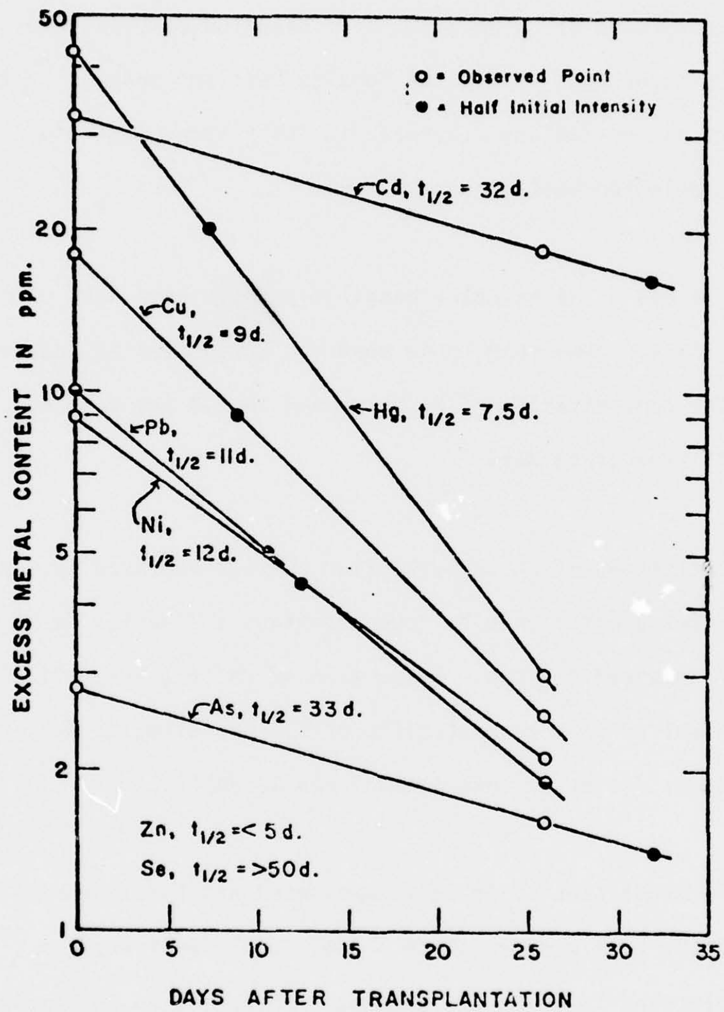

Figure 8. Desorption rates of some metals from *M. edulis* transplanted from Selby Pier to Tomales Bay. The excess of each metal in the transplanted *M. edulis* over the equilibrium concentration of that metal in native *M. edulis* from Tomales Bay is plotted against time after transplantation. Not shown are data for Zn, which equilibrated very rapidly ($t_{1/2} < 5$ days), and Se which equilibrated very slowly ($t_{1/2} > 50$ days).

174 ppm to slightly below Tomales Bay baseline concentrations (111 ppm). The best estimate of Zn half-time was less than 5 days.

It is interesting to compare the concentrations of the test metals in native Mare Island Strait M. edulis, Table 6, p.31 , to Selby Pier baseline concentrations, Table 8, p. 55. Concentrations of the metals Ag, As, Ni, Se, and Zn were equivalent, whereas the concentrations of the metals Cd, Cu, Hg, and Pb were considerably higher in Selby samples, probably as a result of past smelting operations at this site.

4. Lead in Water and Suspended Particulates

The mean concentrations and one standard deviation of Pb in uncentrifuged water, centrifuged water, and in suspended particulates collected at three stations in Mare Island Strait, before, during, and after the dredging periods are presented in Table 9, p. 61.

The concentration of Phase I Pb (soluble Pb plus Pb that is acid extractable from both organic and inorganic particulates <0.6μ esd remaining in the supernate) increased during the first dredging-rainfall period. A similar increase was not observed during the second dredge period. Water samples collected during the second dredge period for Phase I Pb determinations were centrifuged for a longer period, removing suspended particulates >0.2u esd. The Phase I Pb concentrations were considerably lower(<.07ppb) before and during the second dredging period than during the first period collections. The absence of an increase in Phase I Pb in the second period collections, the very low concentrations observed

during this period, and the removal of more suspended material from the samples (>.2μ esd vs. >.6μ esd) suggest that the first dredge period increases resulted from street runoff or some other non-dredging input associated with suspended particulates.

Phase II Pb (total acid extractable fraction) concentrations fluctuated during the study period but were not correlated with dredge periods or with rainfall.

Phase III Pb (total Pb in suspended particulates) concentrations are presented in Table 9, on both a dry weight (mg/kg) and a wet weight (μg/l) basis. The amount of Pb associated with particulate matter removed from the water samples by centrifugation (Phase III Pb) increased during the two periods of dredging and rainfall. The values expressed on a dry weight basis show a factor of 2 increase during the two dredging-rainfall periods indicating a relative elevation of the Pb burden in suspended particulates during these periods. A similar increase is observed in Phase III Pb concentration expressed on a wet weight basis during the first dredge period collections. However, no increase was observed during the second collection period suggesting that the increase in Phase III Pb observed during the first dredge period was perhaps due to an increased transport of Pb-rich suspended particulates into the study area from surface runoff.

The data show that greater than 95% of the total Pb in the water column during these collections was associated with suspended

Table 9. The means and one standard deviation of Pb concentrations observed in water and suspended particulates collected at three stations in Mare Island Strait before, during and after the two dredging periods. Values are expressed as ppb wet and dry weights as indicated.

Collections	I	II*	III*	IV	V*	VI
Phase I Pb (ppb wet weight) (Pb remaining in supernate after centrifugation)	0.11 ±.03	0.36 ±.10	0.34 ±.08	<0.07* --	<0.07* --	--
Phase II Pb (ppb wet weight) (total acid extractable Pb)	3.1 ±.53	2.9 ±1.2	5.8 ±2.0	4.3 ±2.6	3.0 ±.79	6.0 --
Phase III Pb (ppm dry and wet weights). Lead associated with particulates.						
A. (ppm dry wts.)	38 ±2.1	39 ±4.6	57 ±3.5	31 ±6.2	64 ±28.2	39 --
B. (ppb wet wts.)	9 ±5.8	8 ±5.0	26 ±5.5	18 ±10.7	12 ±1.4	25 --
Phase I is X% of Phase III B	1	4	1	<1	<1	--
Phase II is X% of Phase III B	34	36	22	24	25	24

* Dredging occurred during these collections.
**Supernate for collections I-III contained particles <0.6 μ esd, for collections IV and V this was reduced to <0.2 μ esd.

particulates and that less than 1% of the total Pb was in solution or associated with particulate matter ≤0.6μ esd. The percentage of total Pb in Phase I and II presented in Table 9 was calculated relative to Phase III Pb levels. With one exception (Phase I, Collection 2), the percentage of Pb associated with these two phases remained relatively constant through the six collections.

IV. Results of Population Data

The invertebrates that were collected and identified from Mare Island Strait are listed in Table 10, p. 63. The populations of the three benthic species, M. balthica, N. succinea, and A. milleri, collected for metals analyses, were monitored at the subtidal collection stations (Figs. 2 and 3) throughout the period of study.

The mean number and the 95% confidence interval of M. balthica collected at stations NO, SO, DO, and SP (Fig. 2) are presented in Fig. 9 , p. 64 . No differences were observed in the mean number of individuals present at stations NO, SO, and DO with time. At station SP, there was a significant decrease in the mean number of organisms after the second dredging period (Fig. 9). Shell length measurements were made to gather data on the abundance of various size classes of M. balthica and the data for stations SO and WO are presented in Figs. 10A-B,pp. 65-66. The populations at these two stations remained stable during this study. The data also show the appearance of smaller individuals at the beginning of

Table 10.

Inbertebrate Fauna of Mare Island Strait
Solano County, California

Numbers 1-7 are codes; see below

Annelida
- Oligochaeta
  - Tubificidae 2
- Polychaeta
  - Eteone lighti 2
  - Glycinde sp. 2
  - Harmothoe imbricata 6
  - Heteromastus filiformis 2
  - Neanthes succinea 1,2,3
  - Polydora ligni 6
  - Pseudopolydora kempi 6
  - Streblospio benedicti 2
  - Tharyx parvus 6

Arthropoda
- Crustacea
  - Ostracoda
    - Sarsiella zostericola 6
  - Cirripedia
    - Balanus improvisus 7
  - Malacostraca
    - Cumacea - Cumella vulgaris 6
    - Chelifera
      - Tanais vanis 6
    - Isopoda
      - Sphaeroma quoyana 7
      - Synidotea Laticauda 3
    - Amphipoda
      - Ampelisca milleri 1,2
      - Ampithoe valida 6
      - Anisogammarus confervicolus 6
      - Corophium acherusicum 2
      - Corophium insidiosum 6
      - Corophium stimpsoni 6
      - Corophium spinicorne 6
      - Corophium sp. 6
      - Grandidirella japonica 2
      - Melita sp., cf. nitida 7
      - Parapleustes pugettensis 7

Decapoda
- Carides
  - Crangon franciscorum 6
  - Palaemon macrodactylus 3
- Brachyura
  - Cancer magister 7
  - Hemigrapsus oregonensis 6
  - Rhithropanopeus harrisii 3
- Anomura
  - Upogebia pugettensis 6

Mollusca
- Bivalvia
  - Ischadium demissum (=Modiolus) 5
  - Macoma balthica 1,2
  - Musculus senhousia 6
  - Mya arenaria 2
  - Mytilus edulis 3,4
  - Tapes japonica 6
- Gastropoda
  - Nassarius obsoletus 7
  - Odostomia sp. 6

Chordata
- Tunicata
  - Molgula manhattensis 3

1=used for metals analysis in benthic survey
2=used for population analysis in benthic survey
3=used for metals analysis from fouling survey
4=used in transplant study
5=used for intertidal mudflat metals analysis
6=numbers or biomass of incufficient quantity for consideration
7=in sufficient abundance for metals analysis but not included because of time limitations
* Species identified by J. Chapman Amphipod identification confifmed by J. L. Barnard; polyclaetes by D. Reish and molluscs by J. Carlton

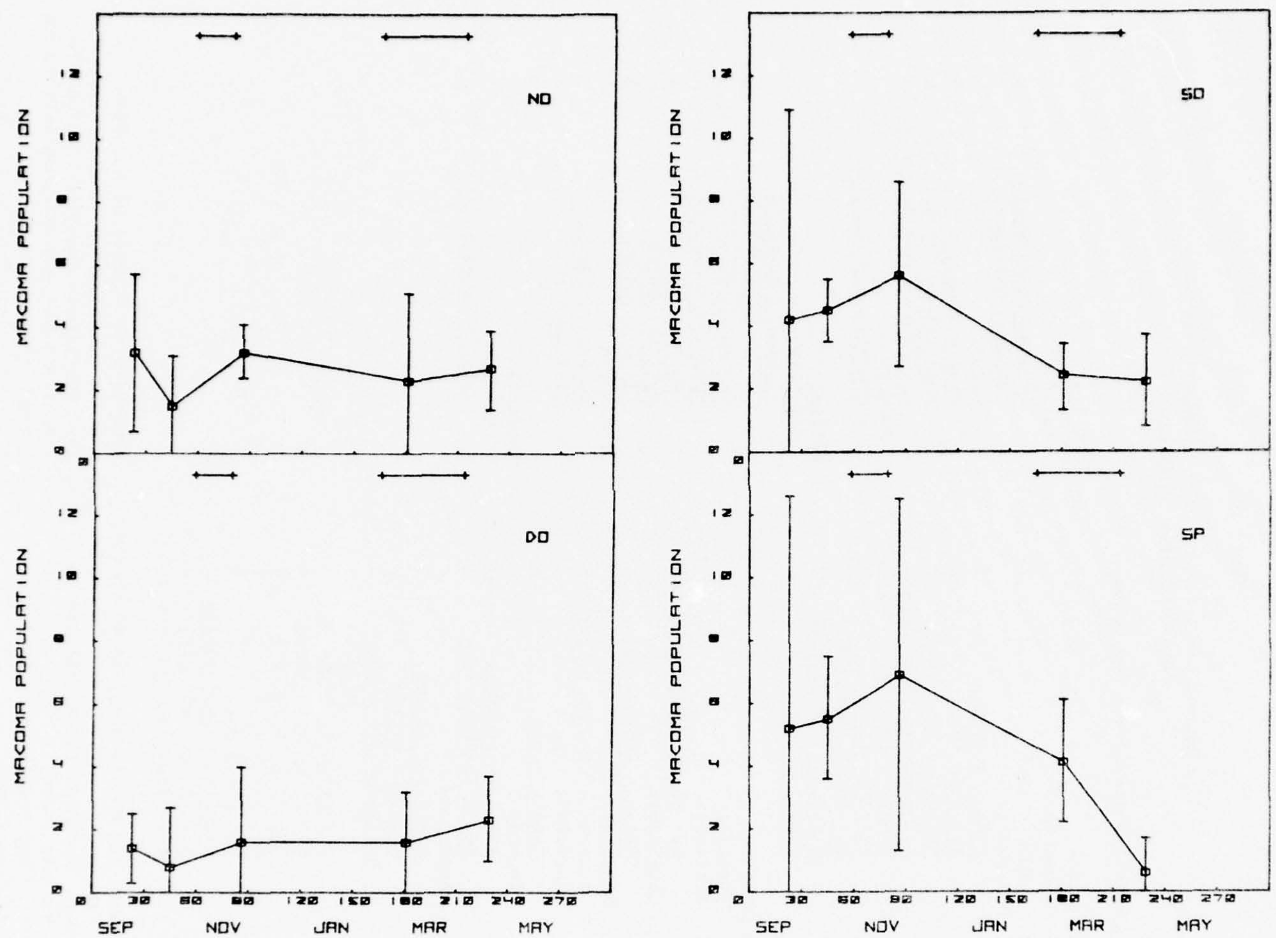

Figure 9. Mean number of M. balthica collected at stations NO,SO,DO, and SP.

XBL 749-1566

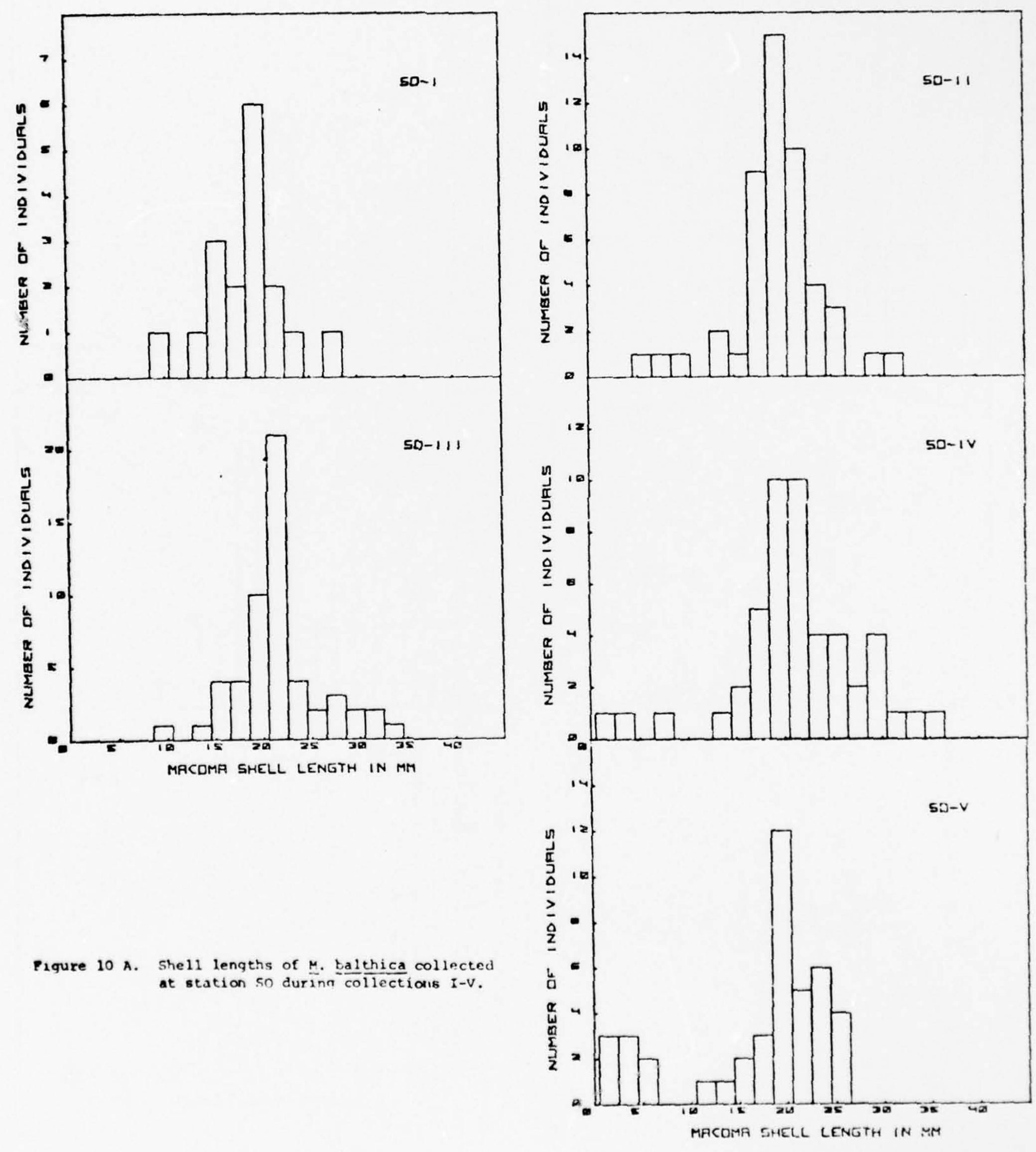

Figure 10 A. Shell lengths of *M. balthica* collected at station SO during collections I-V.

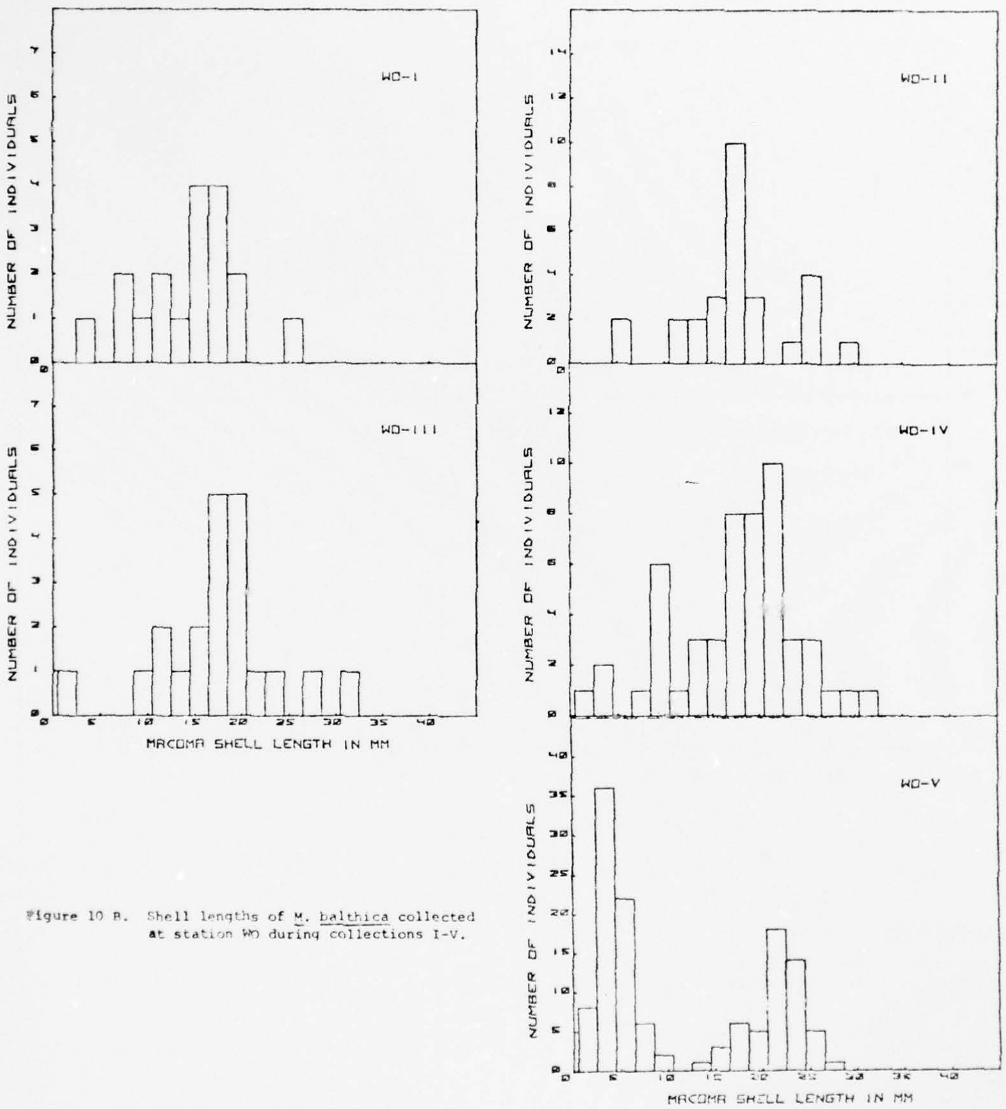

Figure 10 B. Shell lengths of M. balthica collected at station WD during collections I-V.

February. The number of smaller individuals was considerably greater at station WO than at station SO at the end of the study period.

The mean numbers of N. succinea collected at stations NO, SO, DO, and SP are presented in Fig. 11, p. 68. No significant differences were detected in the mean number of individuals at these stations through time.

The population data for A. milleri collected at stations NO, SO, DO, EI, and SP are presented in Fig. 12, p. 69. The mean number of individuals increased slightly prior to the first dredging-rainfall period and decreased significantly after this period (collection III). A. milleri were collected at only two stations during collection IV. The number of individuals was inadequate for either metal or population analyses and no individuals were present at these stations after this period.

Size class data indicate that during the first collection a bimodal size distribution existed with the mean size of individuals increasing through the third collection (Fig. 13, p. 70). As mentioned above, the number of individuals decreased significantly after the first dredging-rainfall period at all stations. The data do not indicate whether this disappearance was due either to dredging activity or lowered salinity or whether the A. milleri populations may not have dispersed en masse from this area. Studies of other amphipod species in this genus indicate that entire populations disperse during the spring in association with reproductive behavior

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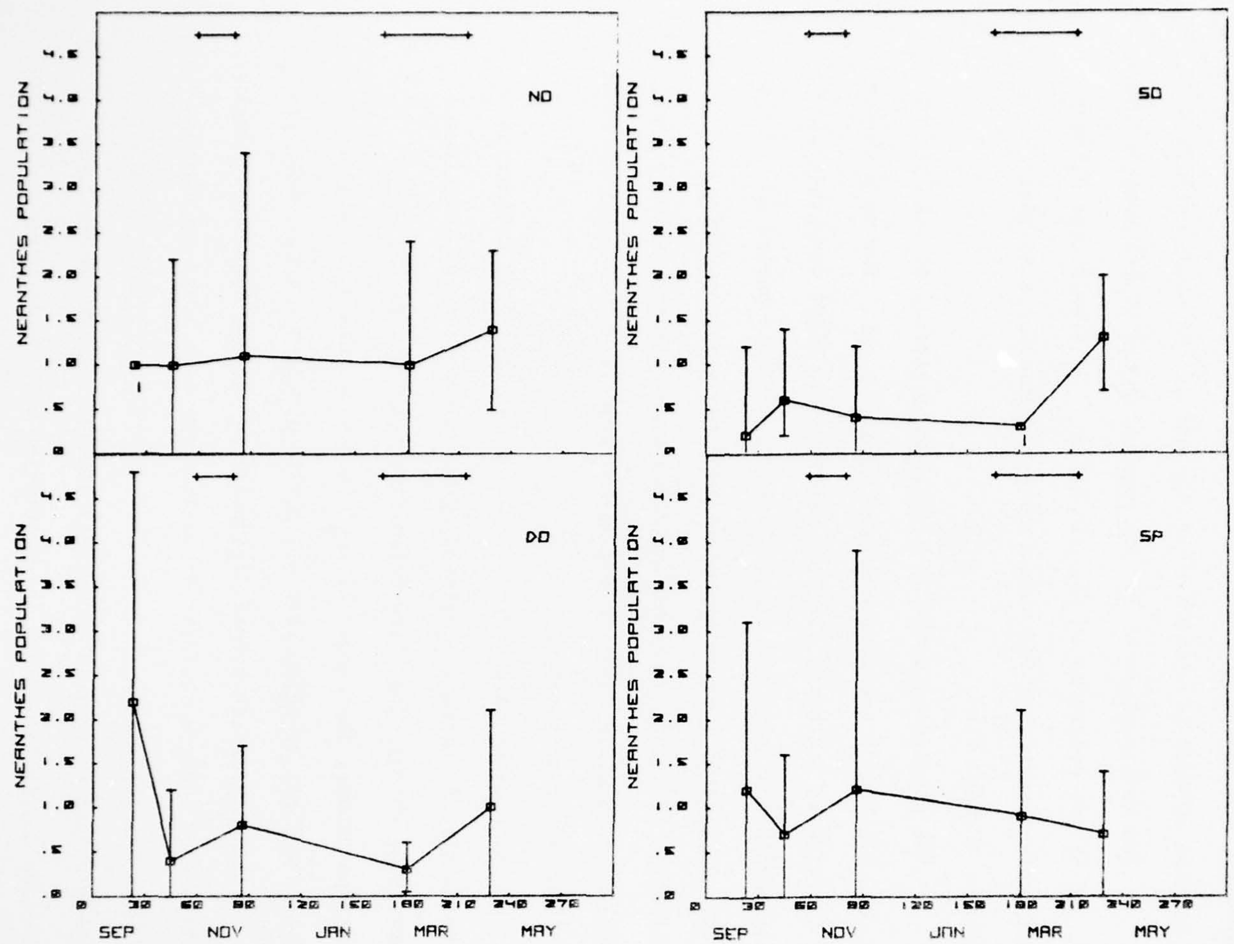
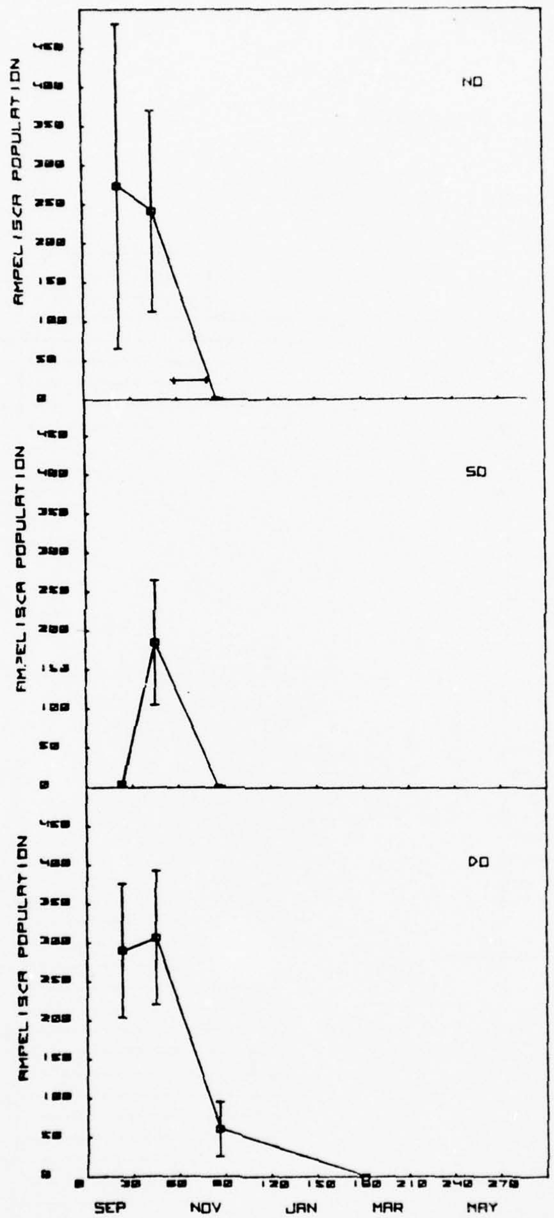


Figure 11. Mean number of N. succinea collected at stations NO,SO,DO, and SP.

XBL 749-1556



XBL 749-1536

Figure 12. Mean number of A. milleri collected at stations NO, SO, and DO.

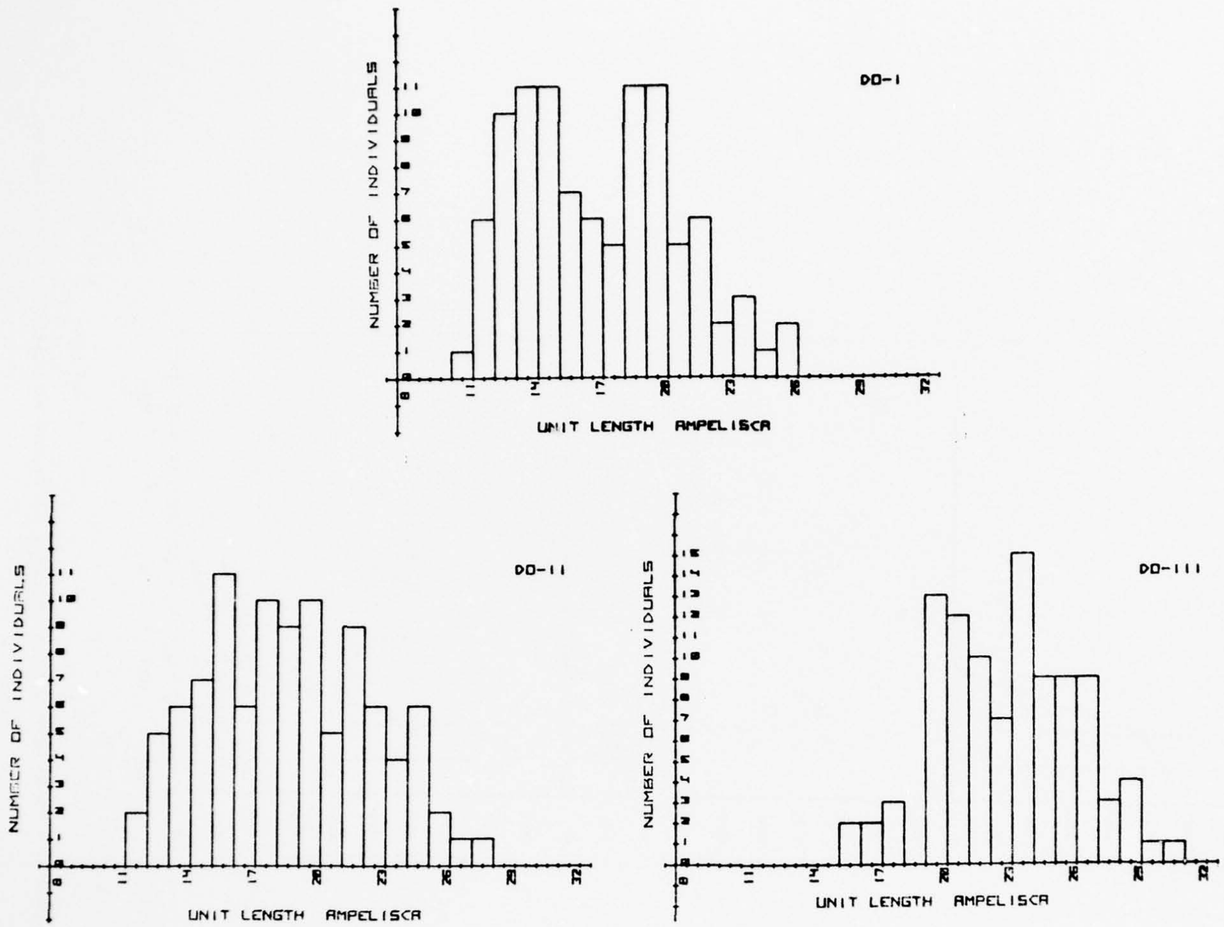


Figure 13. Mean size of individual A. millerí collected at station DO.

XBL 749-1537

(Mills, 1963). Size class analysis of Mare Island Strait populations indicates a similar life history in A. milleri. However, if these populations dispersed during this period the causes are presently unknown.

V. Results of Laboratory Study

The results of the laboratory experiments on the uptake and accumulation of metals by M. balthica are presented in Tables 11 A-C, and 12, pp. 72-75. The M. balthica used in these experiment were collected at station SO during the period between collection IV and V (Table 1, p.11). The concentrations of Ag, Cd, Cu, Pb, and Hg at station SO during these two collections are shown in Appendix Tables II, pp. A 10-18.

As can be seen by comparing the values presented in these two sets of tables, the baseline values of Cu and Pb were equivalent to the average of the mean concentrations of these metals as determined in M. balthica during collections IV and V. The baseline values of Ag and Cd were equivalent to concentrations observed during collection IV, but baseline Hg values were unaccountably higher than Hg concentrations observed during either collection IV or V.

The pattern of uptake and accumulation of the five metals by M. balthica differed for each metal. The results of the nine day exposure experiment show that Cu was significantly desorbed from M. balthica in the control tanks at the two higher salinities as well as in the test tanks to which 2.5 and 5.0 ppb of Cu, as chloride salt, was added.

Table 11 A. Macoma balthica Laboratory Study. Results of nine days exposure of M. balthica to three concentrations of the chloride salts of Cu and Pb in three salinities. Values are expressed as ppm dry weight with 95% confidence limits and sample sizes indicated.

			Element / Days Exposure							
			Copper				Lead			
Tank No.	Assumed Exposure Concentration (ppb)	Salinity	0	3	6	9	0	3	6	9
1	x	25‰	98** (75-120) 5	28 (20-37) 5	25 (20-30) 5	30 (25-35) 5	4.0 (1.6-6.3) 5	1.6 (0.9-2.4) 5	2.0 (0.0-4.0) 5	1.8 (1.3-2.2) 5
2	x + 2.5	"	"	26 (14-39) 5	32 (10-54) 5	29 (21-36) 5	"	2.8 (0.8-4.7) 5	3.7 (2.4-5.1) 5	3.8 (2.6-5.0) 5
3	x + 5.0	"	"	27 (11-43) 5	32 (22-42) 5	30 (20-41) 5	"	2.3 (1.0-3.7) 5	5.0 (3.0-7.0) 5	4.4 (1.8-7.0) 5
4	x + 10.0	"	"	27 (22-32) 5	31 (19-42) 5	37 (29-45) 5	"	4.1 (3.2-5.0) 5	7.1 (5.0-9.3) 5	7.6 (5.6-9.6) 5
5	x	12.5‰	"	62 (43-81) 5	57 (32-83) 5	47 (39-55) 5	"	4.2 (3.2-5.2) 4	4.0 (1.1-6.9) 5	3.3 (2.2-4.5) 5
6	x + 2.5	"	"	66 (44-87) 5	65 (30-101) 5	58 (35-82) 5	"	4.8 (3.8-5.8) 5	4.8 (2.6-7.0) 5	7.7 (4.4-10.9) 5
7	x + 5.0	"	"	70 (39-101) 5	59 (51-67) 5	67 (12-122) 5	"	5.2 (2.3-8.0) 5	7.5 (5.3-9.7) 5	10.0 (3.5-16.0) 5
8	x + 5.0	"	"	75 (56-94)	56 (40-72)	59 (40-79)	"	2.2 (1.4-3.0)	3.8 (2.3-5.4)	6.3 (3.9-8.7)
9	x	5.0‰	"	126 (95-157) 5	127 (102-153) 5	179 (133-226) 5	"	3.9 (2.7-5.1) 5	6.2 (3.7-8.7) 5	7.1 (4.4-9.8) 5
10	x + 2.5	"	"	137 (109-165) 5	122 (99-145) 5	154 (123-185) 5	"	7.7 (5.6-9.9) 5	7.3 (4.8-9.8) 5	9.7 (7.5-11.9) 5
11	x + 5.0	"	"	112 (63-160) 5	144 (60-228) 5	108 (88-127) 5	"	7.7 (5.1-10.3) 5	14.1 (0.0-32) 5	9.8 (5.5-14.2) 5
12	x + 10.0	"	"	155 (122-188)	143 (118-169)	199 (141-257)	"	7.6 (4.9-10.2)	12.3 (4.7-19.8)	16.9 (12.1-21.2)

* Concentrations of Cu and Pb based on reported values in open ocean waters by E.D. Goldberg in (Horne, 1969).

** Concentrations of Cu and Pb in baseline M. balthica collected at station SO (10, March 1974) after purging for three days in filtered 15‰ seawater.

Table 11 B. Macoma balthica Laboratory Study. Results of nine days exposure of M. balthica to three concentrations of the chloride salt of Hg. Values are expressed as ppm dry weight, with 95% confidence limits and sample size indicated.

Tank No.	Assumed Exposure Concentration (ppb)	Salinity	Element / Days Exposure Mercury 0	3	6	9
1	x*	25‰	1.92** (1.5-2.4) 5	.62 (.52-.72) 5	.27 (.22-.31) 5	.26 (.21-.31) 5
2	x + 2.5	"	"	.54 (.47-.62) 5	.42 (.29-.56) 5	.57 (.43-.71) 5
3	x + 5.0	"	"	.87 (.72-1.0) 5	.49 (.41-.56) 5	.64 (.52-.76) 5
4	x + 10.0	"	"	2.31 (1.8-2.8) 5	2.50 (2.0-3.0) 5	3.04 (2.6-3.5) 5
5	x	12.5‰	"	.72 (.41-1.0) 5	.37 (.25-.49) 5	.29 (.23-.34) 5
6	x + 2.5	"	"	.88 (.78-1.0) 5	.44 (.38-.51) 5	.55 (.41-.69) 5
7	x + 5.0	"	"	1.09 (.71-1.5) 5	.74 (.60-.87) 5	.83 (.64-1.1) 5
8	x + 10.0	"	"	.82 (.47-1.2) 5	.99 (.87-1.2) 5	2.44 (1.5-3.4) 5
9	x	5‰	"	1.41 (1.0-1.8) 5	.59 (.50-.68) 5	.41 (.33-1.5) 5
10	x + 2.5	"	"	2,11 (1.3-2.9) 5	.68 (.54-.68) 5	.53 (.40-.64) 5
11	x + 5.0	"	"	1.84 (1.0-2.7) 5	1.05 (.35-1.8) 5	1.13 (.84-1.4) 5
12	x + 10.0	"	"	4.17 (3.7-4.7) 5	3.30 (2.9-3.7) 5	4.02 (2.1-5.9) 5

* Concentration of Hg in seawater based on values reported in open ocean waters by by E.D. Gōldberg in (Horne, 1969).

** Concentration of Hg in baseline M. balthica collected at station SO (10, March) after purging for three days in filtered, 15‰ seawater.

Table 11 C. Macoma balthica Laboratory Study. Results of nine day exposure of M. balthica to x*+ 10.0 ppb Ag and Cd chloride salts in 5‰ seawater. Values are expressed as ppm dry weight with 95% confidence limits and sample sizes indicated.

			Element / Days Exposure					
			Silver			Cadmium		
Tank No.	Assumed Exposure Concentration (ppb)	Salinity	0	3	9	0	3	9
9	x*	5.0‰	2.1** (0.6-3.5) 5	1.3 (0.3-2.3) 5	3.1 (1.3-4.8) 5	0.9** (0.0-2.1) 5	0.6 (0.0-1.6) 5	0.8 (0.0-2.3) 5
12	x + 10.0	5.0‰	"	3.4 (1.9-4.9) 5	6.8 (4.0-9,5) 5	"	1.8 (0.1-3.5) 5	8.0 (3.4-12.6) 5

* Concentrations of Ag and Cd in seawater based on values reported in open ocean waters by E.D. Goldberg in (Horne, 1969).

**Concentrations of Ag and Cd in M. balthica collected at station SO (10 March, 1974) after purging for three days in filtered 15‰ seawater.

Table 12. *Macoma balthica* Laboratory Study. Desorption of the metals As, Ni , Se and Zn from *M. balthica* exposed for nine days to three concentrations of Ag, Cd, Cu, Hg, and Pb, as chloride salts, under three salinity regimes. Values are expressed as ppm dry weight with 95% confidence limits and sample sizes indicated.

		Element / Days Desorption											
		Arsenic			Nickel			Selenium			Zinc		
Tank No.	Salinity	0	3	9	0	3	9	0	3	9	0	3	9
1	25‰	12.0* (10-13) 5	6.2 (4.7-7.7) 5	4.4 (3.8-5.0) 5	15.6* (12-19) 5	4.4 (3.1-5.7) 5	3.8 (2.9-4.7) 5	6.0* (5.6-6.4) 5	3.6 (2.9-4.3) 5	3.2 (2.7-3.6) 5	811* (648-974) 5	441 (335-546) 5	450 (341-520) 5
4	25‰	"	4.7 (4.0-5.4) 5	5.1 (2.8-7.3) 4	"	3.9 (2.9-4.9) 5	3.0 (2.5-3.6) 4	"	3.5 (3.0-4.0) 5	3.5 (3.1-3.9) 4	"	375 (280-470) 5	485 (360-610) 4
5	12.5‰	"	7.8 (6.8-8.9) 5	6.3 (5.1-5.7) 5	"	5.3 (4.0-6.7) 5	5.1 (3.9-6.4) 5	"	4.7 (4.2-5.3) 5	4.0 (3.2-4.7) 5	"	695 (554-836) 5	628 (418-838) 5
8	12.5‰	"	7.2 (4.5-8.0) 5	6.5 (4.8-8.2) 5	"	6.2 (4.8-7.6) 5	4.5 (3.6-5.5) 5	"	4.6 (4.0-5.3) 5	4.2 (3.3-5.0) 5	"	504 (389-619) 5	485 (360-610) 5
9	5.0‰	"	7.8 (7.0-8.6) 5	10.5 (9.5-11.6) 5	"	6.4 (5.2-7.6) 5	6.5 (5.8-7.2) 5	"	4.8 (4.2-5.4) 5	5.6 (5.3-6.0) 5	"	480 (397-563) 5	668 (453-883) 5
12	5.0‰	"	9.2 (8.0-10.5) 5	10.1 (8.5-11.7) 5	"	7.0 (5.1-8.9) 5	10.5 (1.7-19.3) 5	"	5.3 (4.3-6.4) 5	6.0 (5.5-6.4) 5	"	645 (388-942) 5	696 (514-878) 5

*Concentration of As, Ni, Se, and Zn in *M. balthica* collected from station SO (10 March,1974) and purged for 3 days in filtered 15‰ seawater.

Copper was accumulated by *M. balthica* in both the control and test tanks receiving either $5^{o}/oo$ seawater alone or $5^{o}/oo$ seawater plus 10 ppb Cu. Copper appears, therefore, to be desorbed rapidly at the higher salinities and lower metal concentrations and accumulated slightly at the lowest salinity and highest metal exposure concentration.

Lead values decreased by a factor of two in the $25^{o}/oo$ control animals from the baseline concentration (4.0 ppm) but remained constant in the $12.5^{o}/oo$ and $5^{o}/oo$ control clams. After three days exposure to x + 10 ppb Pb, only the clams in the lowest salinity ($5^{o}/oo$) tanks showed accumulation. After nine days exposure, clams in all tanks receiving x + 10 ppb Pb solutions accumulated Pb above the baseline levels; with the highest accumulation occurring in the test tank with the lowest salinity and highest Pb concentration (Table 11 A).

Interpretation of the Hg accumulation data was difficult owing to the unaccountably high (1.92 ppm) Hg concentration in baseline *M. balthica* (Table 11 B). In general, desorption of Hg occurred in *M. balthica* exposed to x, x + 2.5, and x + 5.0 ppb Hg in all three salinities. The greatest desorption occurred at the higher salinities and lowest exposure concentrations. As with Cu and Pb, mercury was accumulated by *M. balthica* in all three salinities in tanks receiving x + 10 ppb Hg. The greatest accumulation occurred in clams exposed to the lowest salinity (Table 11 B).

Silver and Cd determinations were performed only on the $5^{o}/oo$

control clams and those exposed to x + 10 ppb Ag and Cd in $5^{o}/oo$ seawater owing to limited analytical time. The results of these analyses are presented in Table 11 C. The data show that Ag and Cd were accumulated by M. balthica above baseline levels. Silver values doubled after nine days exposure and concentrations of Cd in M. balthica increased by an order of magnitude during this study.

The results of the three-way anova test of the Cu, Pb, and Hg laboratory data are presented in Table 13. The significant interaction terms shown in this table indicate that the effect of one variable on metal uptake was affected by another variable. The data for Hg concentrations in M. balthica during this laboratory study illustrates this point (Fig. 14, p. 79).

The lines on each graph are not parallel, particularly at x + 10 ppb. This graph (which includes baseline values) illustrates that each resultant concentration of Hg in M. balthica exposed to the three salinities was dependent on exposure time. If these graphs were superimposed to represent the interaction of salinity and concentration through time, the lines would again not be parallel, indicating interaction or non-linearity of the effects of salinity and concentration on the uptake of Hg.

It is clear that, although there were first order interactions between salinity, concentration, and time of exposure on uptake and accumulation through time, the lower salinities and higher concentrations of the test metals resulted in the greatest metal concentrations in M. balthica. Conversely, the greatest desorption from M. balthica occurred in those animals exposed to the highest salinities.

Table 13. *Macoma balthica* Laboratory Study. Results of multi-variate analysis*.

Factor	Copper F ratio (df) P	Lead F ratio (df) P	Mercury F ratio (df) P
Time	6.42 (1) 0.0148	46.4 (1) 0.0001	21.4 (2) 0.0001
Concentration	5.11 (1) 0.0286	70.0 (1) 0.0001	270 (3) 0.0001
Salinity	169.5 (2) 0.0001	49.7 (2) 0.0001	94.1 (2) 0.0001
Time vs. Concentration	0.001 (1) 0.975	20.6 (1) 0.0001	11.1 (6) 0.0001
Time vs. Salinity	9.12 (2) 0.0005	9.33 (2) 0.0004	11.7 (4) 0.0001
Concentration vs. Salinity	0.986 (2) 0.381	11.2 (2) 0.0002	26.0 (6) 0.0001
Time vs. Concentration vs. Salinity	0.170 (2) 0.844	0.885 (2) 0.420	1.51 (12) 0.1280
Error (Mean square)	571 (46)	3.46 (46)	0.150 (144)

* Method- Univariant-multivariant analysis of variance, covariance and regression. Version No. 5, March, 1972. Copyrighted and distributed by National Resources Inc., 215 Kenwood Ave., Ann Arbor, Mich. 48103.

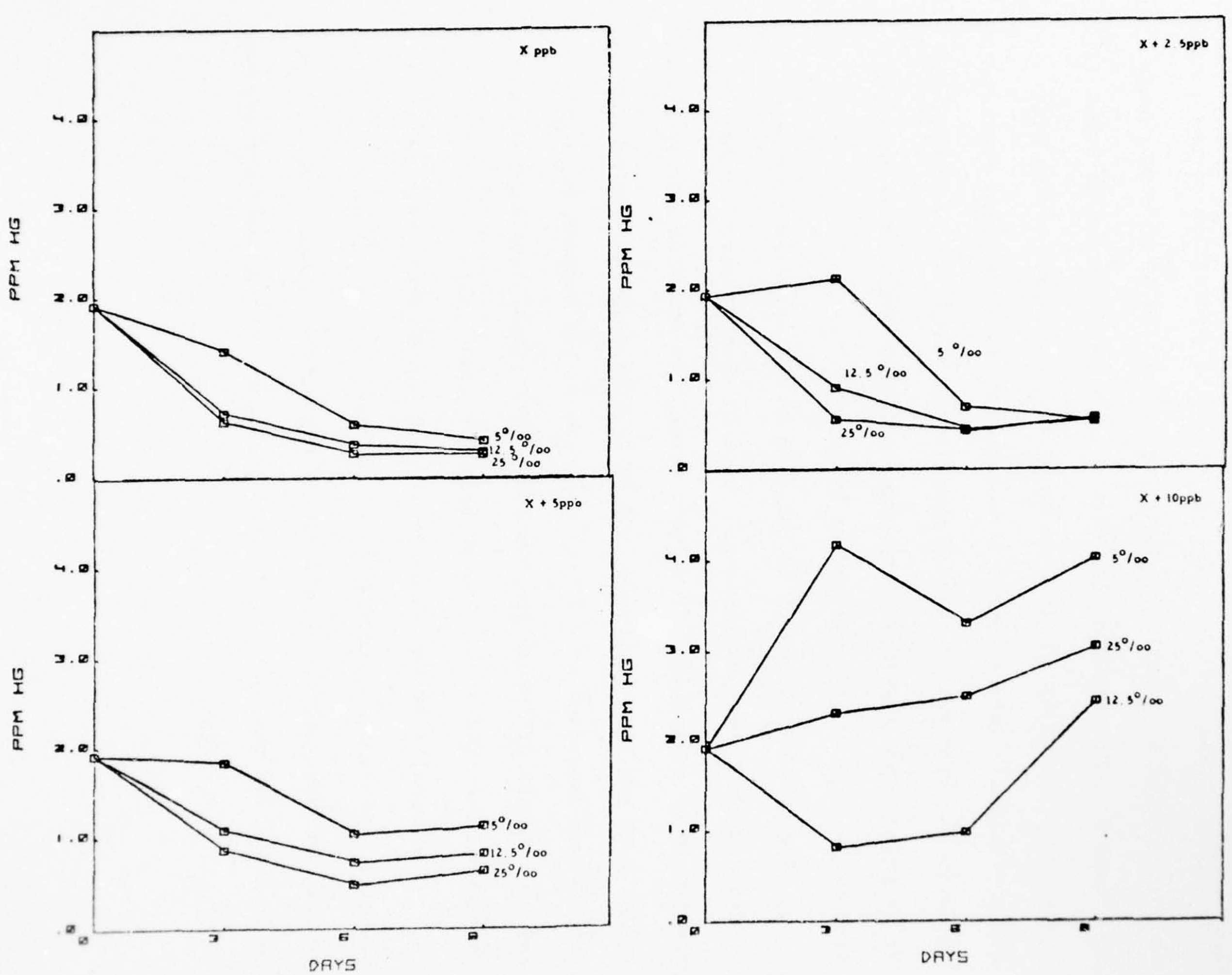


Figure 14. The interaction of salinity and concentration on Hg accumulation in M. balthica.

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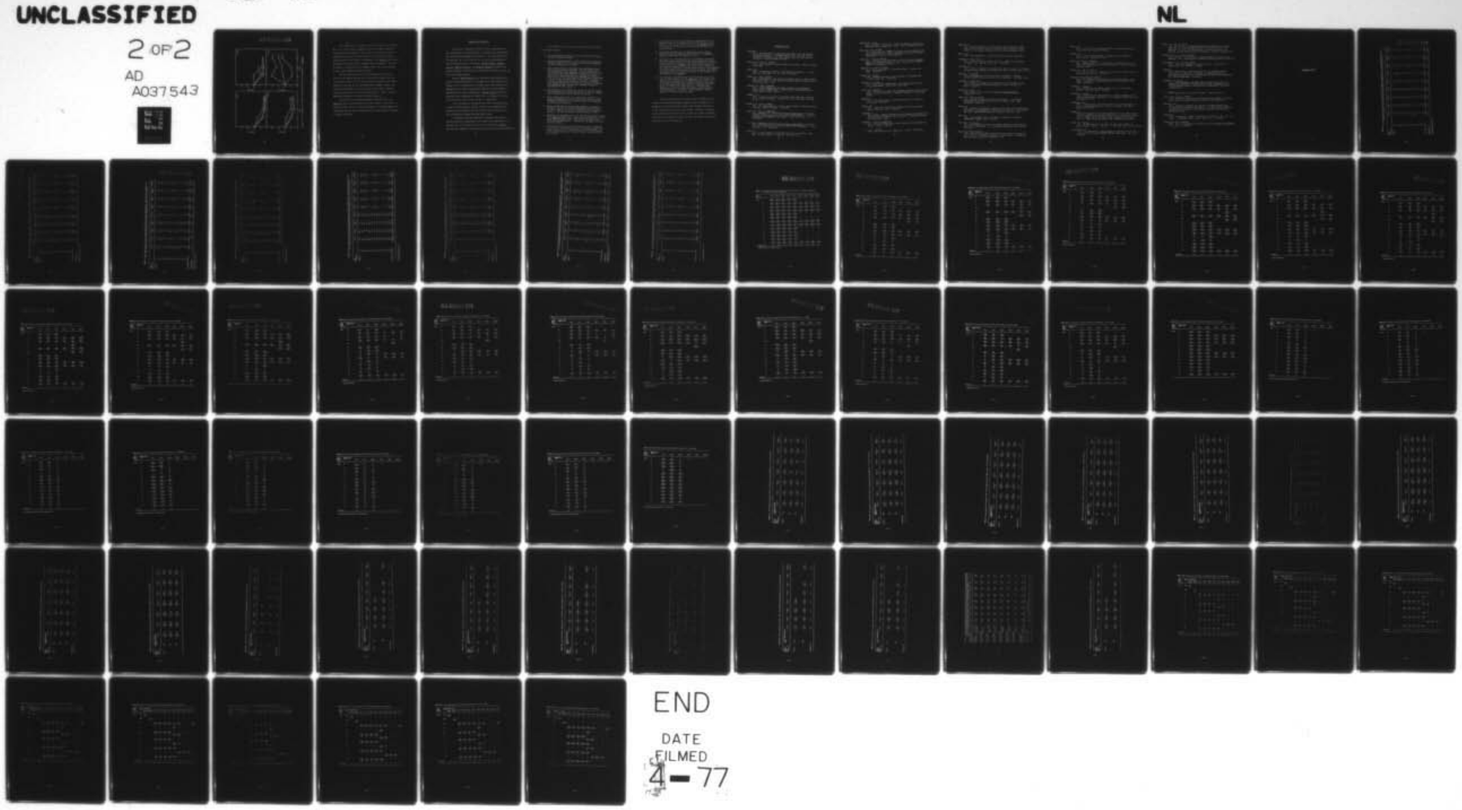

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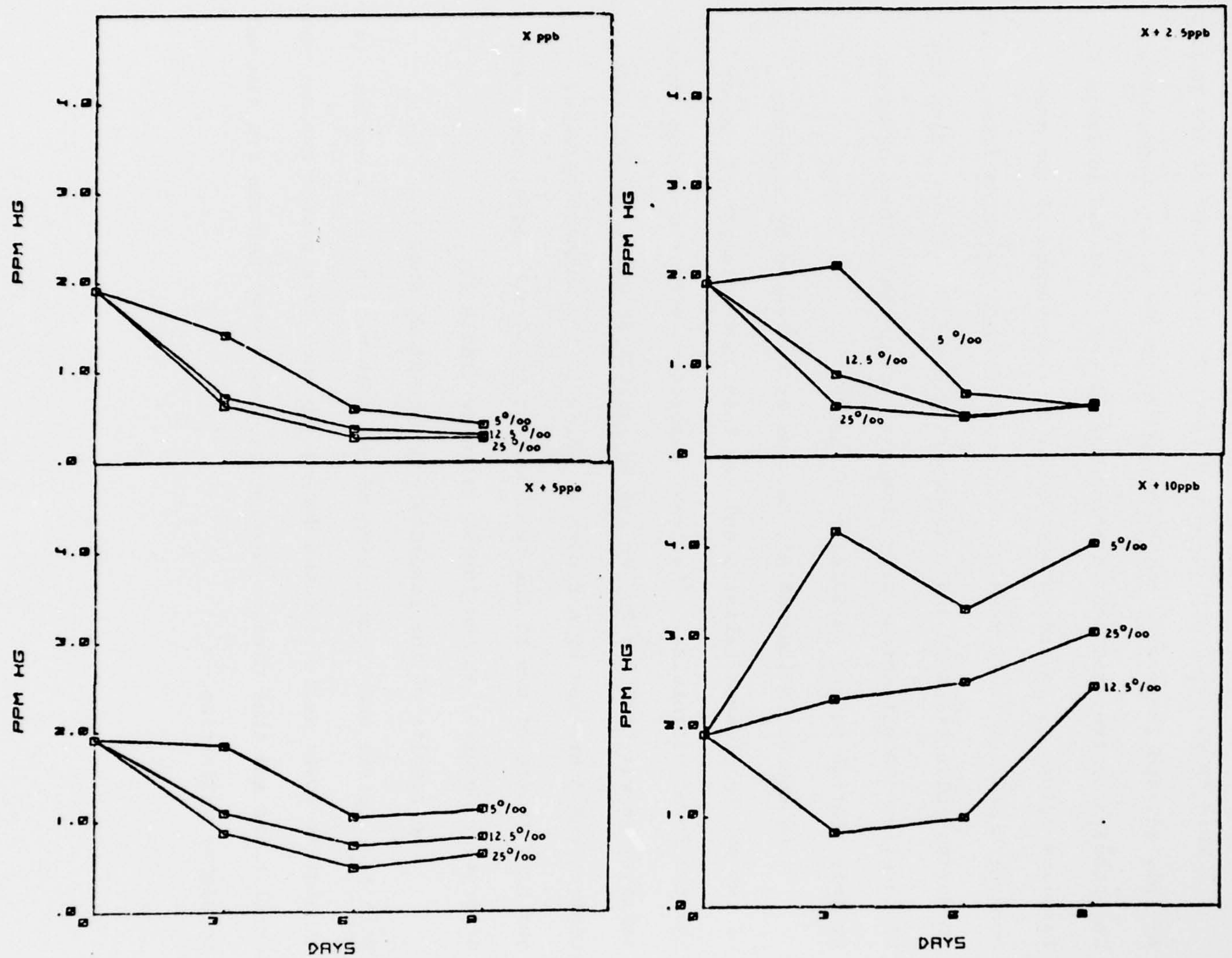

Figure 14. The interaction of salinity and concentration on Hg accumulation in M. balthica.

This experiment also allowed a study of desorption of the metals As, Ni, Se, and Zn from M. *balthica* exposed to the above conditions. The results of the analyses of these metals are presented in Table 12. Baseline values of As and Se were equal to the average of the mean concentrations of these metals as determined in *M. balthica* from station SO during collections IV and V (Appendix Table II b and h). Zinc and Ni baseline concentrations were somewhat higher than values observed at this station during collections IV and V.

The concentrations of As, Se, and Zn decreased by a factor of two at the highest salinity and by less than a factor of two at the two lower salinities. The least desorption occurred at the lowest salinity as was true for Cu, Pb and Hg control animals. Nickel concentrations decreased by a factor of three at the highest salinity and by a factor of two at the two lower salinities. Again, the least desorption occurred at the lowest salinity (Table 12).

The results of the Laboratory Uptake Study show that, in *M. balthica*, uptake and accumulation of the test metals, if it occurs, is greater at lower salinities and during exposure to elevated ambient concentrations and that greater desorption occurs when animals are exposed to higher salinities.

SUMMARY AND CONCLUSIONS

The effects of dredging activities in Mare Island Strait on the concentration of nine heavy metals in sediments and invertebrates were studied during September 1973- May 1974. The concentrations of the metals Ag, As, Cd, Cu, Hg, Ni, Pb, Se, and Zn were monitored in surface sediments and the invertebrates *Macoma balthica*, *Neanthes succinea*, *Ampelisca milleri*, and *Ischadium demissum* collected from stations adjacent to and outside of the dredge zone before, during, and after two dredging periods.

Mussels, *Mytilus edulis*, were transplanted from Tomales Bay to stations inside and outside of the dredge zone in Mare Island Strait. Changes in the concentrations of the above metals were monitored and compared with the metal concentrations observed in native mussels in Mare Island Strait and at Tomales Bay. *Mytilus edulis* from nearby Selby Pier were transplanted to Tomales Bay to determine the desorption rates of the nine test metals over a 27 day period.

Lead concentrations were monitored in water and suspended particulates collected before, during, and after two dredging periods. Analyses were performed on raw water aliquots and on water that was was centrifuged to separate suspended particulates.

A laboratory study was conducted to determine the effects of salinity and metal concentration on the uptake and accumulation of the chloride salts of the metals Ag, Cd, Cu, Pb, and Hg by *M. balthica*. The clams were exposed to three salinities during this nine day experiment.

The following is a list of conclusions based on the results of the above studies:

1. The two periods of dredging activity coincided with the two periods of heaviest rainfall.

2. Salinity decreased greatly in Mare Island Strait during the period of study, with the lowest salinities being observed at stations further up the Strait.

3. Metal concentrations in sediments and invertebrates fluctuated during the period of study. With the exception of Ni concentrations in *N. succinea*, no significant changes in metal levels were associated with dredging activities. The results of Ni determinations in *N. succinea* are questionable because of the high probability of finding a significant *t* ratio, at the .05 significance level, from a population of *t* ratios as large as is presented. Further, the changes were significantly greater at stations outside of the dredge zone suggesting that, if anything, dredging inhibits Ni accumulation in this species.

4. Concentrations of the metals Cd, Cu, Hg, Ni, Pb, Se, and Zn were generally two to three times higher in native *M. edulis* than in Tomales Bay controls during this period.

5. Metal concentrations were not significantly different in *M. edulis* transplanted to stations within the dredge zone than in mussels transplanted to stations outside of the dredging area during any collection.

6. Mussels transplanted to Mare Island appeared to accumulate the metals Cu, Ni, and Zn above Tomales Bay control concentrations. However, no metal was accumulated by transplanted mussels to the levels observed in mussels native to MIS.

7. Desorption of the metals As, Cd, Cu, Hg, Ni, Pb, and Zn occurred in *M. edulis* transplanted to Tomales Bay from Selby Pier during the 27 day desorption study. The order of desorption was Zn > Hg > Cu > Pb > Ni > Cd > As. Selenium did not appear to desorb from this species.

8. Concentrations of Pb in uncentrifuged water and in suspended particulates increased during the first dredging period. Comparable changes were not observed during the second dredging period suggesting that the observed changes resulted from surface runoff.

9. The results of the nine day laboratory study showed that the greatest uptake and accumulation of the chloride salts of the metals ag, Cd, Cu, Hg, and Pb occurred in M. Balthica exposed to the highest concentrations of these metals in the lowest salinity water.

10. The greatest desorption of the metals As, Ni, Se, and Zn during the nine day laboratory study occured in M. balthica exposed to water with the highest salinity.

11. The results of a three-way analysis of variance of the laboratory data showed significant first order interaction between salinity and time, influencing the concentrations of the metals Cu, Hg, and Pb in M. balthica. Significant interactions were also observed between salinity and concentration, influencing the uptake and accumulation of the metals Hg and Pb by M. balthica. These data support the observations that the lowest salinities and highest metal concentrations resulted in the greatest metal accumulations in M. balthica.

12. The increases in concentrations of the metals Ag, Cu, Hg, Zn and to a lesser extent Pb in M. balthica at all stations after each period of dredging and a general increase in these concentrations during the study, correlate well with the results of the laboratory study which showed the greatest uptake of metals to occur at the lowest salinity. The heavy rains during each of the two respective dredge periods resulted in marked decreases in salinity at those times and a general decrease in salinity during the study.

The data obtained during the field studies indicate that the collection and analytical methods employed during this study were reproducible and sensitive enough to detect small natural fluctuations in the concentrations of the nine test metals. Therefore, if changes in the concentrations of these metals occurred as a result of dredging activities, the changes were either less than these small natural fluctuations or were of short duration.

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APPENDIX TABLES

Table Ia. Silver concentrations in benthic surface sediments collected from Mare Island Channel. Values expressed as ppm dry weight, n = 1. Mean concentration and 95% confidence limits for all stations combined at every collection are also listed.

Date Collection		8 Oct 73 I	24 Oct 73 II	14 Nov 73 III	24 Nov 73 IV	21 Dec 73 V	12 Feb 74 VI	13 Mar 74 VII	28 Mar 74 VIII	28 Apr 74 IX
Station	NI	1.1	2.7	1.1	4.9	---	---	---	---	---
	NO	1.9	2.7	2.5	2.2	1.1	4.0	2.9	2.1	2.7
	SI	1.5	0.9	2.9	1.2	3.4	4.8	2.5	3.1	2.3
	SO	2.4	1.5	1.8	1.1	2.9	2.3	1.3	2.1	2.7
	TI	3.1	2.6	2.6	3.5	---	---	---	---	---
	TO	1.4	2.0	2.3	1.5	---	---	---	---	---
	DI	3.5	1.6	1.8	3.7	3.2	2.2	1.2	1.8	1.3
	DO	2.3	1.4	1.7	1.5	2.3	3.7	<0.9	1.4	1.6
	EI	<0.9	2.6	3.2	2.0	---	---	---	---	---
	EO	<1.0	0.9	1.0	0.9	---	---	---	---	---
	WI	2.8	2.2	2.3	1.0	---	---	---	---	---
	WO	2.5	2.7	1.6	1.2	---	---	---	---	---
	SP	1.8	2.2	1.9	2.4	2.5	1.6	2.2	1.7	1.6
All Stations (Mean)		2.0 (1.4-2.5)	2.2 (1.8-2.6)	2.2 (1.8-2.5)	2.2 (1.5-2.9)	2.6 (1.7-3.7)	3.1 (1.9-4.3)	1.8 (1.0-2.6)	2.0 (1.4-2.6)	2.0 (1.4-2.6)
Counting Error		± 0.9	± 0.9	± 0.9	± 1.0	± 1.0	± 1.0	± 1.0	± 0.9	± 0.9

Minimum Probable Error = 5%.

Table Ib. Arsenic concentrations in benthic surface sediments collected from Mare Island Channel. Values expressed as ppm dry weight. n = 1. Mean concentration and 95% confidence limits for all stations combined at every collection are also listed.

Date Collection		8 Oct 73 I	24 Oct 73 II	14 Nov 73 III	24 Nov 73 IV	21 Dec 73 V	12 Feb 74 VI	13 Mar 74 VII	28 Mar 74 VIII	28 Apr 74 IX
Station	NI	9.9	6.2	14.1	7.4	---	---	---	---	---
	NO	13.8	9.2	16.3	12.9	14.4	11.3	10.6	16.5	13.5
	SI	10.4	10.2	15.9	14.2	12.4	9.9	12.1	14.6	8.4
	SO	11.5	12.5	9.2	16.4	10.8	12.4	16.6	13.3	9.0
	TI	10.4	9.8	12.5	12.4	---	---	---	---	---
	TO	13.2	15.2	8.8	10.1	---	---	---	---	---
	DI	15.1	14.2	11.7	11.0	14.7	12.8	13.9	12.9	10.4
	DO	15.4	10.4	12.6	11.5	8.4	9.7	13.5	17.2	10.1
	EI	11.1	10.8	11.0	9.7	---	---	---	---	---
	EO	7.4	8.8	7.1	7.6	---	---	---	---	---
	WI	13.9	8.5	15.4	9.9	---	---	---	---	---
	WO	10.8	8.2	10.9	7.9	---	---	---	---	---
	SP	11.4	14.8	10.7	9.6	19.7	15.0	26.2	13.6	24.8
All Stations (Mean)		11.9 ---	10.7 (9-12)	10.8 (9-13)	10.8 (9-13)	13.4 (10-17)	11.9 (10-14)	15.5 (10-21)	14.7 (13-16)	12.7 (6-19)
Counting Error		± 2	± 2	± 2	± 2	± 2	± 2	± 2	± 2	± 2

Minimum Probable Error ≈ 5%.

Table Ic. Cadmium concentrations in benthic surface sediments collected from Mare Island Channel. Values expressed as ppm dry weight, n = 1. Mean concentration and 95% confidence limits for all stations combined at every collection are also listed.

Date Collection		8 Oct 73 I	24 Oct 73 II	14 Nov 73 III	24 Nov 73 IV	21 Dec 73 V	12 Feb 74 VI	13 Mar 74 VII	28 Mar 74 VIII	28 Apr 74 IX
Station	NI	1.6	2.4	2.9	2.4	---	---	---	---	---
	NO	<1.0	1.4	<1.0	<1.0	2.8	2.9	<1.0	2.6	2.2
	SI	2.6	<1.0	3.4	<1.0	2.0	3.6	2.8	1.4	1.5
	SO	1.9	1.2	2.3	2.4	2.5	3.1	2.3	1.3	3.3
	TI	2.1	1.7	3.4	4.3	---	---	---	---	---
	TO	<1.0	<1.0	2.0	1.2	---	---	---	---	---
	DI	1.6	2.4	<1.0	3.5	3.2	3.7	2.4	3.7	2.1
	DO	<1.0	1.3	2.7	2.1	3.1	1.5	1.9	1.6	2.7
	EI	<1.0	1.1	<1.0	2.0	---	---	---	---	---
	EO	<1.0	1.8	2.5	2.1	---	---	---	---	---
	WI	1.6	2.4	2.4	<1.0	---	---	---	---	---
	WO	1.3	2.4	2.0	1.6	---	---	---	---	---
	SP	1.2	2.5	2.6	1.9	1.1	3.1	2.2	1.9	2.0
All Stations	(Mean)	1.2 (0.8-1.7)	2.2 (1.8-2.6)	2.2 (1.7-2.7)	2.0 (1.3-2.6)	2.5 (1.7-3.2)	3.0 (2.2-3.8)	2.1 (1.4-2.7)	1.9 (1.0-2.8)	2.3 (1.7-2.9)
Counting Error		± 1.0	± 1.0	± 1.0	± 1.0	± 1.0	± 1.0	± 1.0	± 1.0	± 1.0

Minimum Probable Error = 5%.

Table Id. Copper concentrations in benthic surface sediments collected from Mare Island Channel. Values expressed as ppm dry weight, n = 1. Mean concentration and 95% confidence limits for all stations combined at every collection are also listed.

Date Collection		8 Oct 73 I	24 Oct 73 II	14 Nov 73 III	24 Nov 73 IV	21 Dec 73 V	12 Feb 74 VI	13 Mar 74 VII	28 Mar 74 VIII	28 Apr 74 IX
Station	NI	86.3	95.1	93.6	97.4	---	---	---	---	---
	NO	89.6	86.5	99.5	103	103	80.9	90.4	81.6	99.7
	SI	94.4	115	89.8	96.2	87.5	95.7	98.4	89.5	93.0
	SO	90.3	107	96.9	89.6	79.0	96.6	99.0	87.3	88.7
	TI	95.1	84.3	78.3	96.8	---	---	---	---	---
	TO	94.4	90.1	97.6	95.8	---	---	---	---	---
	DI	74.5	74.4	62.9	73.6	75.9	77.9	111	96.7	80.8
	DO	89.0	83.0	84.7	82.2	71.0	84.3	91.9	80.5	78.0
	EI	65.1	67.4	72.5	79.6	---	---	---	---	---
	EO	59.3	59.3	80.4	62.3	---	---	---	---	---
	WI	75.5	71.9	65.5	72.3	---	---	---	---	---
	WO	73.4	89.4	70.3	77.1	---	---	---	---	---
	SP	88.1	78.9	80.8	83.6	101	92.2	103	74.4	102
All Stations	(Mean)	80.1 (71.9-88.2)	84.9 (75.6-94.0)	82.5 (74.9-90.0)	85.3 (78-92.6)	86.3 (72.9-100)	87.9 (80.0-95.9)	98.9 (91.4-106)	85.0 (77.2-92.8)	90.3 (80.6-100)

Minimum Probable Error = 5%.

Table Ie. Nickel concentrations in benthic surface sediments collected from Mare Island Channel. Values expressed as ppm dry weight, n = 1. Mean concentration and 95% confidence limits for all stations combined at every collection are also listed.

Date Collection		8 Oct 73 I	24 Oct 73 II	14 Nov 73 III	24 Nov 73 IV	21 Dec 73 V	12 Feb 74 VI	13 Mar 74 VII	28 Mar 74 VIII	28 Apr 74 IX
Station	NI	82.5	90.3	91.1	98.8	---	---	---	---	---
	NO	93.1	83.3	110	118	98.0	96.1	84.0	83.5	88.5
	SI	86.4	102	101	95.9	73.3	88.1	94.3	106	95.3
	SO	100	103	113	86.2	74.4	101	97.5	98.0	94.3
	TI	89.7	89.5	88.3	97.4	---	---	---	---	---
	TO	87.0	91.5	107	110	---	---	---	---	---
	DI	79.2	67.0	77.5	86.8	64.4	75.1	114	120	92.0
	DO	97.8	86.4	92.4	87.2	67.1	108	86.7	121	87.0
	EI	75.4	73.6	93.7	95.9	---	---	---	---	---
	EO	68.4	67.6	85.8	78.9	---	---	---	---	---
	WI	70.2	68.9	75.8	78.9	---	---	---	---	---
	WO	69.4	73.9	85.2	84.5	---	---	---	---	---
	SP	92.7	75.5	81.6	95.0	79.2	96.2	114	101	86.5
All Stations (Mean)		81.1 (74.4-87.8)	82.5 (75.0-89.9)	92.5 (85.2-99.8)	93.3 (86.3-100)	76.1 (64.1-88.0)	94.2 (82.7-106)	98.4 (85.4-111)	105 (90.7-119)	90.6 (86.8-94.4)

Minimum Probable Error = 5%.

Table If. Lead concentrations in benthic surface sediments collected from Mare Island Channel. Values expressed as ppm dry weight, n = 1. Mean concentration and 95% confidence limits for all stations combined at every collection are also listed.

Date Collection		8 Oct 73 I	24 Oct 73 II	14 Nov 73 III	24 Nov 73 IV	21 Dec 73 V	12 Feb 74 VI	13 Mar 74 VII	28 Mar 74 VIII	28 Apr 74 IX
Station	NI	55	66	52.3	65.2	---	---	---	---	---
	NO	49	60	46.8	58.6	55	46	45	36	44
	SI	64	84	78.8	64.6	75	63	57	38	48
	SO	52	53	53.8	44.6	46	32	31	34	40
	TI	74	51	47.2	62.6	---	---	---	---	---
	TO	51	57	53.7	61.9	---	---	---	---	---
	DI	54	53	43.1	58.8	44	33	47	36	36
	DO	53	54	47.1	44.4	47	29	38	31	34
	EI	41	46	48.4	44.7	---	---	---	---	---
	EO	56	37	45.8	51.7	---	---	---	---	---
	WI	39	58	35.6	50.1	---	---	---	---	---
	WO	48	55	44.8	46.3	---	---	---	---	---
	SP	50	44	44.6	44.1	47	45	47	43	50
All Stations (Mean)		51 ---	55 (48-62)	49.4 (43-55)	53.5 (48-59)	52 (41-64)	41 (28-54)	44 (35-53)	36 (33-40)	42 (35-48)
Counting Error		± 6	± 6	± 6	± 6	± 5	± 5	± 6	± 5	± 5

Minimum Probable Error = 5%.

Table Ig. Selenium concentrations in benthic surface sediments collected from Mare Island Channel. Values expressed as ppm dry weight, n = 1. Mean concentration and 95% confidence limits for all stations combined at every collection are also listed.

Date Collection		8 Oct 73 I	24 Oct 73 II	14 Nov 73 III	24 Nov 73 IV	21 Dec 73 V	12 Feb 74 VI	13 Mar 74 VII	28 Mar 74 VIII	28 Apr 74 IX
Station	NI	2.4	1.9	1.9	2.4	---	---	---	---	---
	NO	2.6	1.9	1.3	2.3	<1.1	2.9	≤1.2	1.7	2.0
	SI	1.3	2.9	<0.8	1.3	3.3	2.4	2.8	1.8	<1.2
	SO	<1.0	3.9	1.9	2.1	1.6	2.6	<1.2	2.0	2.9
	TI	1.7	2.6	<1.0	1.7	---	---	---	---	---
	TO	2.2	2.1	2.1	2.8	---	---	---	---	---
	DI	2.5	1.9	2.1	0.7	3.2	2.3	<1.2	3.2	2.7
	DO	≤1.3	1.9	<0.2	<0.5	2.2	1.3	≤1.2	2.1	2.9
	EI	2.3	<1.3	1.9	<0.8	---	---	---	---	---
	EO	2.1	1.7	2.8	<0.3	---	---	---	---	---
	WI	<1.3	3.5	1.4	2.0	---	---	---	---	---
	WO	2.7	2.0	<0.9	1.6	---	---	---	---	---
	SP	3.6	2.5	2.4	1.4	1.3	3.6	3.6	1.6	2.9
All Stations (Mean)		2.0 ---	1.3 (1.9-2.8)	1.6 (1.4-1.9)	1.5 (1.1-2.1)	2.1 (1.1-3.1)	2.5 (1.8-3.3)	1.8 (0.7-2.9)	2.0 (1.3-2.9)	2.0 (1.0-2.9)
Counting Error		± 1.3	± 1.3	± 1.2	± 1.2	± 1.1	± 1.1	± 1.2	± 1.1	± 1.2

Minimum Probable Error = 5%.

Table Ih. Zinc concentrations in benthic surface sediments collected from Mare Island Channel. Values expressed as ppm dry weight, n = 1. Mean concentration and 95% confidence limits for all stations combined at every collection are also listed.

Date Collection		8 Oct 73 I	24 Oct 73 II	14 Nov 73 III	24 Nov 73 IV	21 Dec 73 V	12 Feb 74 VI	13 Mar 74 VII	28 Mar 74 VIII	28 Apr 74 IX
Station	NI	151	172	155	163	---	---	---	---	---
	NO	165	154	167	169	185	143	153	142	162
	SI	163	187	175	181	150	173	166	148	156
	SO	169	173	164	152	142	155	163	141	150
	TI	184	147	136	168	---	---	---	---	---
	TO	152	163	161	172	---	---	---	---	---
	DI	158	139	121	140	142	139	181	155	141
	DO	162	156	154	139	128	138	152	140	134
	EI	125	132	142	149	---	---	---	---	---
	EO	119	114	142	123	---	---	---	---	---
	WI	134	127	124	135	---	---	---	---	---
	WO	137	158	141	135	---	---	---	---	---
	SP	148	141	139	153	153	137	165	134	161
All Stations (Mean)		147 (134-160)	151 (139-163)	140 (131-149)	152 (142-163)	150 (131-169)	148 (133-162)	163 (153-174)	143 (136-150)	151 (139-162)

Minimum Probable Error = 5%.

Table Ii. Mean mercury concentrations, 95% confidence limits of replicates[1] for benthic surface sediments collected from Mare Island Channel. Values expressed as ppm dry weight.

Date Collection		8 Oct 73 I	24 Oct 73 II	14 Nov 73 III	24 Nov 73 IV	21 Dec 73 V	12 Feb 74 VI	13 Mar 74 VII	28 Mar 74 VIII	26 Apr 74 IX
Station	NI	.566 (.449-.682) 4	.626 (.604-.648) 4	.648 (.548-.747) 4	.587 (.562-.612) 5	.588 (.547-.630) 4	---	---	---	---
	NO	.510 (.434-.587) 4	.593 (.488-.698) 4	.492 (.328-.655) 4	.506 (.474-.538) 5	.474 (.460-.489) 4	.500 (.468-.531) 4	.446 (.406-.486) 4	.515 (.476-.553) 4	.419 (.411-.427) 4
	SI	.525 (.518-.532) 3	.700 (.693-.707) 3	.532 (.476-.587) 4	.603 (.568-.637) 5	.500 (.464-.535) 4	.573 (.536-.609) 4	.408 (.381-.434) 4	.588 (.371-.549) 4	.393 (.369-.417) 4
	SO	.479 (.440-5.7) 4	.423 (.360-.485) 4	.514 (.449-.579) 4	.512 (.476-.548) 4	.439 (.396-.482) 5	.371 (.350-.392) 5	.379 (.300-.457) 4	.426 (.391-.461) 4	376 (.359-.396) 4
	TI	.480 (.407-.553) 4*	.428 (.409-.447) 4	.470 (.453-.487) 4	.532 (.491-572) 4	.451 (.423-.480) 3	---	---	---	---
	TO	.427 (.416-.437) 4	.482 (.417-.547) 4	.478 (.425-.531) 4	.503 (.469-.536) 4	.411 (.382-.439) 4	---	---	---	---
	DI	.521 (.376-.665) 4	.712 (.655-.769) 4	.377 (.323-.432) 4	.645 (.568-.721) 5	.587 (.541-.634) 4	.352 (.310-.395) 7	.423 (.373-.473) 5	.350 (.330-.371) 4	.366 (.356-.377) 5
	DO	.465 (.412-.519) 4	.424 (.359-.489) 4	.453 (.412-.494) 4	.422 (.384-.460) 4	.396 (.364-.428) 5	.355 (.290-.420) 5	.368 (.362-.373) 3	.363 (.338-.389) 4	.322 (.296-.349) 5
	EI	.348 (.324-.372) 4	.330 (.306-.354) 4	.402 (.376-.548) 4	.421 (.397-.445) 4	.378 (.336-.420) 4	---	---	---	---
	EO	.281 (.264-.268) 4	.300 (.252-.348) 4	.375 (.336-.413) 4	.329 (.305-.354) 5	.267 (.238-.296) 4	---	---	---	---
	WI	.450 (.393-.507) 4	.382 (.346-.418) 4	.392 (.372-.412) 4	.443 (.421-.465) 4	.394 (.376-.411) 4	---	---	---	---
	WO	.458 (.341-.576) 4	.442 (.298-.585) 4	.395 (.338-.452) 4	.400 (.374-.427) 4	.318 (.310-.326) 4	---	---	---	---
	SP	.423 (.372-.473) 4	.444 (.424-.464) 3	.385 (.278-.492) 4	.415 (.378-.451) 4	.632 (.573-.692) 5	.794 (.769-.819) 5	.756 (.721-.790) 4	.558 (.520-.597) 4	.805 (.712-.896) 5
All Stations (Mean)		.456	.484	.455	.486	.449	.491	.463	.467	.447

1) Replicate analyses of single samples of sediment.

Table IIa. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Macoma balthica Silver	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	1.1 (0.7-1.5) 5	0.8 (0.3-1.2) 5	1.6 (0.9-2.2) 5			
	NO	1.0 (0.5-1.4) 5	1.3 (0.7-1.8) 5	1.5 (0.9-2.2) 5	1.2 (0.6-1.9) 5	2.9 (2.3-3.4) 5	1.9 (1.3-2.6) 5
	SI	1.3 (0.9-1.7) 5	1.0 (0.6-1.5) 5	1.5 (0.8-2.2) 5	2.2 (1.8-2.2) 5	3.0 (1.9-4.0) 9	4.2 (3.4-5.1) 5
	SO	1.1 (0.8-1.4) 10	1.2 (1.0-1.5) 10	2.6 (1.5-3.6) 5	2.3 (1.7-2.9) 5	4.6 (3.4-5.7) 5	3.4 (2.1-4.8) 5
	SO-O					4.0 (3.5-4.6) 5	2.8 (2.1-3.4) 5
	TI	1.1 (0.6-1.6) 5	0.8 (0.3-1.2)	1.7 (1.3-2.0) 5			
	TO	1.6 (0.4-2.7) 3	1.4 (1.2-1.6) 5	2.9 (1.3-4.6) 5			
	DI	1.1 (0.7-1.5) 5	0.6 (0.2-0.9) 5	2.6 (2.0-3.1) 5	2.2 (1.6-2.9) 5	3.7 (3.1-4.2) 5	6.4 (5.3-7.4) 5
	DO	1.2 (0.7-1.7) 5	0.9 (0.2-1.6) 5	1.6 (1.1-2.0) 5	2.6 (1.7-3.4) 4	2.8 (2.0-3.5) 5	3.7 (1.2-6.2) 5
	BI	2.3 --- 1	0.9 --- 1	2.8 (1.4-4.2) 3			
	BO	1.7 --- 1	1.2 (0.4-2.0) 4	1.8 --- 1			
	WI	1.2 (0.4-2.0) 5	0.9 (0.2-1.6) 5	2.8 (1.8-3.7) 5			
	WO	1.4 (0.4-2.4) 5	1.0 (0.3-1.8) 5	1.4 (0.4-2.3) 5			
	SP	1.9 (1.3-2.5) 5	1.5 (1.2-1.7) 5	2.3 (1.4-3.2) 5	2.6 (2.2-3.7) 5	3.4 (2.5-4.6) 5	3.6 (2.5-4.8) 5
Counting Error		± 0.5	± 0.5	± 0.5	± 0.5	± 0.5	± 0.5

Table IIb. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	*Macoma balthica* Arsenic	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	11.0 (9.9-12.1) 6	9.9 (9.2-10.5) 10	9.7 (8.7-10.6) 9			
	NO	8.9 (8.4-9.4) 10	10.4 (9.0-11.7) 10	9.9 (9.2-10.7) 9	7.7 (7.0-8.4) 10	10.2 (9.4-11.1) 10	9.3 (8.7-10.0) 10
	SI	8.6 (8.0-9.2) 6	8.8 (8.1-9.5) 10	9.8 (7.3-12.4) 9	7.1 (5.9-8.3) 5	8.6 (7.2-10.0) 7	8.5 (7.9-9.2) 7
	SI-D					10.4 (9.7-11.2) 5	
	SO	12.6 (11.8-13.3) 10	16.3 (14.2-18.4) 10	14.2 (11.6-16.8) 10	9.6 (8.4-10.9) 10	14.0 (12.2-15.7) 7	11.4 (10.5-12.3) 10
	SO-D					12.8 (11.1-14.6) 10	10.4 (9.5-11.3) 10
	TI	9.7 (8.9-10.5) 5	10.7 (9.8-11.5) 10	9.3 (8.4-10.3) 10			
	TO	10.2 (9.2-11.1) 3	11.0 (10.0-11.9) 10	12.8 (10.6-15.0) 6			
	DI	9.9 (8.5-11.4) 6	9.9 (8.8-11.0) 8	10.4 (9.2-11.7) 6	7.7 (7.0-8.4) 10	10.0 (9.4-10.6) 10	10.8 (9.9-11.7) 5
	DO	13.5 (12.5-14.5) 8	12.9 (11.8-14.0) 10	13.2 (11.8-14.7) 10	11.2 (9.6-12.9) 7	11.1 (9.6-12.7) 10	9.7 (9.0-11.0) 10
	BI	11.3 --- 1	9.7 --- 1	16.2 (13.3-19.1) 3			
	BO	16.1 --- 1	21.7 (* -58.3) 3	11.5 --- 1			
	WI	11.3 (10.4-12.2) 10	10.6 (9.5-11.7) 9	9.7 (9.0-10.4) 10			
	WO	9.4 (8.8-10.0) 10	11.5 (10.5-12.6) 10	12.2 (11.5-12.9) 10			
	SP	9.8 (9.4-10.3) 8	11.8 (10.1-13.5) 8	11.4 (10.5-12.4) 9	11.1 (9.9-12.3) 9	12.9 (11.9-14.0) 10	15.5 (14.2-16.8) 10
Counting Error		± 0.5	± 0.5	± 0.5	± 0.4	± 0.5	± 0.5

* Negative confidence limit.

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Table IIc. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	*Macoma balthica* Cadmium	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	MI	1.2 (0.9-1.5) 5	0.9 (0.4-1.4) 5	<0.5 --- 5			
	MO	0.6 (0.0-1.4) 5	0.8 (0.4-1.2) 5	0.9 (0.6-1.2) 5	0.7 (0.0-1.4) 5	1.4 (1.2-1.7) 5	0.4 (0.0-0.9) 5
	SI	1.0 (0.9-1.0) 5	1.0 (0.5-1.6) 5	0.7 (0.3-1.1) 5	0.6 (0.4-0.8) 5	1.9 (1.4-2.4) 9	1.7 (1.2-2.2) 5
	SO	<0.5 --- 10	1.2 (0.8-1.5) 10	1.3 (0.9-1.8) 5	1.2 (1.0-1.3) 5	2.4 (1.8-2.9) 5	1.5 (1.0-1.9) 5
	SO-D					1.3 (0.8-1.8) 5	0.9 (0.4-1.4) 5
	TI	<0.5 --- 5	1.1 (0.9-1.3) 5	0.9 (0.2-1.6) 5			
	TO	0.7 (* -1.5) 3	0.7 (0.0-1.4) 5	1.6 (0.4-2.7) 5			
	DI	0.8 (0.0-1.6) 5	2.6 (1.9-3.4) 5	0.8 (0.2-1.5) 5	1.5 (1.1-2.0) 5	1.8 (1.3-2.2) 5	2.6 (2.0-3.3) 5
	DO	0.7 (0.3-1.1) 5	<0.5 --- 5	<0.5 --- 5	1.0 (0.4-1.6) 4	0.8 (0.4-1.2) 5	1.6 (0.9-1.3) 5
	EI	1.8 --- 1	<0.5 --- 1	1.1 (0.2-2.0) 3			
	EO	1.9 --- 1	3.4 (0.0-7.2) 4	0.9 --- 1			
	WI	<0.5 --- 5	0.9 (0.5-1.4) 5	0.9 (0.4-1.4) 5			
	WO	0.8 (0.6-1.0) 5	1.0 (0.3-1.6) 5	<0.5 --- 5			
	SP	1.4 (1.1-1.8) 5	0.7 (0.4-1.0) 5	0.8 (0.3-1.3) 5	0.6 (0.1-1.1) 5	1.5 (0.5-2.4) 5	1.6 (1.0-2.2) 5
Counting Error		± 0.5	± 0.5	± 0.5	± 0.5	± 0.5	± 0.5

* Negative confidence limit.

Table IId. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	<u>Macoma balthica</u> Copper	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	36.7 (31.1-42.3) 6	24.2 (21.6-26.9) 10	66.8 (60.6-76.7) 9			
	NO	35.2 (31.2-39.2) 10	28.3 (25.4-31.2) 10	67.8 (57.8-71.8) 9	60.1 (54.7-65.5) 10	70.4 (60.5-80.3) 10	76.0 (64.7-83.4) 10
	SI	45.2 (42.3-48.2) 6	39.0 (32.6-45.4) 10	65.2 (46.2-84.3) 9	55.9 (47.2-64.7) 5	55.7 (33.7-77.7) 7	80.3 (72.0-88.7) 7
	SI-D					82.2 (67.3-97.1) 5	
	SO	54.4 (46.1-62.7) 10	45.5 (33.7-57.4) 10	68.3 (52.0-84.5) 10	79.8 (72.8-86.9) 10	128 (108-149) 7	124 (112-135) 10
	SO-D					125 (108-141) 10	92.7 (83.9-102) 10
	TI	42.3 (32.0-52.6) 5	22.8 (20.4-25.2) 10	56.4 (46.0-66.7) 10			
	TO	48.4 (24.2-72.5) 3	36.2 (31.2-41.3) 10	66.9 (52.8-81.0) 5			
	DI	29.1 (21.3-36.8) 6	23.9 (21.1-25.1) 8	76.2 (68.5-83.9) 6	70.8 (64.0-77.7) 10	93.1 (85.1-101) 10	103 (88.4-117) 5
	DO	48.8 (43.0-54.5) 8	27.3 (23.4-31.1) 10	64.5 (58.7-70.3) 10	73.9 (56.5-91.3) 7	71.9 (58.2-85.6) 10	73.4 (60.5-87.2) 10
	EI	41.9 --- 1	51.7 --- 1	80.4 (44.4-116) 3			
	EO	34.7 --- 1	19.0 (2.3-35.8) 3	52.2 --- 1			
	WI	29.0 (25.6-32.4) 10	27.2 (23.9-30.6) 9	76.1 (54.4-98.0) 10			
	WO	23.3 (20.6-26.0) 10	29.1 (24.0-34.2) 10	49.4 (32.2-66.7) 4			
	SP	56.5 (51.3-61.7) 8	31.6 (25.3-37.9) 8	57.1 (48.3-66.0) 9	102 (78.5-125) 9	100 (84.2-116) 10	102 (85.6-119) 10
Counting Error		± 1.1	± 1.0	± 1.4	± 1.3	± 1.5	± 1.5

Table IIe. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Macoma balthica Nickel	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	3.6 (2.9-4.3) 6	2.0 (1.6-2.4) 10	8.0 (6.4-9.6) 9			
	NO	3.3 (2.6-3.9) 10	2.7 (1.9-3.4) 10	7.8 (6.8-8.8) 9	5.5 (5.0-6.1) 10	7.0 (6.3-7.7) 10	6.8 (5.9-7.6) 10
	SI	13.2 (6.3-20.0) 6	3.1 (2.6-3.6) 10	20.5 (15.3-25.7) 9	9.4 (5.1-13.7) 5	36.5 (5.3-67.6) 7	8.5 (7.0-10.0) 7
	SI-D					9.2 (6.1-12.3) 5	
	SO	3.8 (2.6-5.0) 10	3.0 (2.3-3.8) 10	6.3 (5.0-7.6) 10	10.1 (6.9-13.4) 10	12.7 (10.1-15.3) 7	9.0 (8.0-10.1) 10
	SO-D					8.8 (7.5-10.1) 10	6.2 (5.6-6.8) 10
	TI	16.4 (1.8-31.0) 5	1.6 (1.1-2.2) 10	14.5 (11.9-17.1) 10			
	TO	3.0 (0.8-5.3) 4	1.8 (1.3-2.3) 10	24.1 (20.1-27.5) 6			
	DI	3.1 (2.1-4.1) 6	2.9 (2.2-3.5) 8	10.0 (7.8-12.2) 6	5.7 (4.9-6.4) 9	7.1 (7.0-8.5) 10	13.8 (11.2-16.5) 5
	DO	5.0 (4.0-5.9) 5	2.2 (1.8-2.6) 10	14.8 (11.4-18.2) 10	9.8 (5.4-14.3) 7	6.7 (5.9-7.6) 10	6.7 (5.8-7.6) 10
	RI	6.0 --- 1	3.0 --- 1	25.4 (19.3-31.5) 3			
	RO	33.0 --- 1	8.4 (* -22.2) 3	25.7 --- 1			
	WI	14.4 (6.0-22.1) 10	1.8 (1.6-2.1) 9	17.1 (16.2-18.0) 10			
	WO	4.7 (3.2-6.3) 10	2.3 (1.7-3.0) 10	18.4 (13.4-23.5) 10			
	SP	28.9 (19.5-38.3) 8	2.0 (1.5-2.4) 8	19.8 (16.0-23.7) 9	8.0 (6.7-9.3) 9	8.4 (7.3-9.5) 10	23.2 (20.2-26.2) 10
Counting Error		± 0.8	± 0.7	± 0.9	± 0.8	± 0.9	± 0.8

* Negative confidence limit.

Table IIf. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	*Macoma balthica* Lead *	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 IV
Station	NI	1.7 (1.1-2.2) 6	0.8 (0.3-1.4) 10	2.5 (1.8-3.3) 9			
	NO	1.2 (0.8-1.7) 10	1.5 (1.0-2.0) 10	2.8 (2.2-3.3) 9	1.6 (1.1-2.1) 10	1.5 (1.1-1.8) 10	1.0 (0.5-1.5) 10
	SI	3.3 (2.4-4.3) 6	4.9 (4.0-5.8) 10	12.3 (9.4-15.3) 10	3.4 (3.1-3.6) 4	9.8 (2.0-17.5) 7	2.8 (2.3-3.4) 7
	SI-D					4.9 (3.1-6.8) 5	
	SO	1.6 (1.0-2.1) 10	1.4 (1.1-1.8) 10	2.1 (1.2-2.9) 10	2.6 (1.6-3.9) 10	6.8 (2.9-10.7) 7	2.4 (1.7-3.1) 10
	SO-D					3.1 (2.0-4.2) 10	1.5 (1.2-1.9) 10
	TI	2.2 (1.3-3.1) 5	1.1 (0.7-1.5) 10	10.3 (8.5-12.0) 10			
	TO	2.1 (1.9-2.3) 3	0.9 (0.5-1.2) 10	8.1 (4.4-11.7) 6			
	DI	1.5 (0.6-2.4) 6	2.0 (0.5-3.5) 8	3.2 (2.1-4.3) 6	1.4 (0.1-2.6) 10	1.9 (1.2-2.6) 10	4.3 (3.2-5.4) 4
	DO	2.3 (1.6-3.1) 8	1.0 (0.5-1.5) 10	4.1 (3.1-5.1) 10	2.3 (0.6-4.0) 7	1.6 (0.6-2.5) 10	1.3 (0.8-1.8) 10
	EI	3.2 --- 1	2.2 --- 1	7.9 (5.7-10.1) 3			
	EO	<0.9 --- 1	7.1 (* -26.8) 3	7.4 --- 1			
	WI	1.0 (0.4-1.6) 10	<0.9 --- 9	6.0 (5.2-6.8) 10			
	WO	< 0.9 --- 10	<0.9 -- 10	6.3 (4.8-7.7) 10			
	SP	2.7 (2.1-3.4) 8	<0.9 --- 7	7.6 (6.2-8.9) 9	2.2 (1.8-2.6) 9	2.0 (1.3-2.6) 10	5.8 (4.5-7.2) 10
Counting Error		± 0.9	± 0.9	± 0.9	± 0.8	± 0.9	± 0.9

* Negative confidence limit.

Table IIg. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Macoma balthica Zinc	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	247 (228-266) 6	265 (231-299) 10	353 (308-389) 9			
	NO	231 (223-239) 10	278 (230-326) 10	391 (315-467) 9	338 (304-371) 10	634 (506-762) 10	525 (464-586) 10
	SI	330 (291-369) 6	349 (295-403) 10	477 (315-640) 9	355 (254-457) 5	479 (326-631) 7	564 (495-633) 7
	SI-D					587 (461-713) 5	
	SO	374 (278-470) 10	556 (421-690) 10	663 (342-985) 10	561 (448-674) 10	568 (524-613) 7	658 (521-794) 10
	SO-D					751 (561-940) 10	546 (471-621) 10
	TI	306 (203-409) 5	357 (243-471) 10	371 (332-410) 10			
	TO	278 (165-391) 3	299 (247-350) 10	442 (301-582) 6			
	DI	263 (210-316) 6	329 (272-386) 8	395 (327-463) 6	390 (320-459) 10	679 (608-749) 10	1090 (760-1410) 5
	DO	359 (255-464) 8	267 (235-298) 10	400 (286-515) 10	462 (358-567) 7	512 (384-641) 10	602 (511-594) 10
	EI	319 --- 1	255 --- 1	398 (273-523) 3			
	EO	362 --- 1	131 (* -267) 3	168 --- 1			
	WI	292 (244-340) 10	371 (312-431) 9	415 (328-502) 10			
	WO	264 (203-324) 10	406 (297-515) 10	382 (330-432) 10			
	SP	264 (229-300) 8	425 (306-545) 8	394 (320-468) 9	426 (378-475) 9	672 (613-732) 10	852 (753-951) 10
Counting Error		± 2	± 2	± 2	± 2	± 3	± 3

* Negative confidence limit.

Table IIh. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Macoma balthica Selenium	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	4.8 (4.4-5.3) 6	4.8 (4.5-5.1) 10	4.7 (4.2-5.3) 9			
	NO	4.6 (4.2-5.0) 10	5.2 (4.9-5.5) 10	4.8 (4.5-5.2) 9	4.0 (3.6-4.4) 10	6.4 (6.1-6.8) 10	5.3 (4.9-5.6) 10
	SI	5.3 (4.8-5.7) 6	4.8 (4.3-5.2) 10	5.0 (3.9-6.1) 9	4.9 (3.3-5.5) 5	3.9 (2.1-5.7) 7	5.0 (4.7-5.3) 7
	SI-D					6.0 (5.6-6.4) 5	
	SO	6.7 (6.4-7.0) 10	7.0 (6.7-7.3) 10	6.3 (5.8-6.8) 10	4.7 (4.3-5.0) 10	6.6 (6.0-7.1) 7	5.7 (5.5-5.9) 10
	SO-D					7.0 (6.3-7.8) 10	4.9 (4.6-5.3) 10
	TI	5.3 (4.7-5.9) 5	5.2 (4.9-5.6) 10	4.5 (4.2-4.8) 10			
	TO	5.2 (4.8-5.6) 3	5.6 (5.1-6.0) 10	5.3 (4.5-6.2) 6			
	DI	5.0 (4.3-5.8) 6	4.6 (4.2-4.9) 8	4.9 (4.2-5.6) 6	4.9 (4.4-5.4) 10	6.5 (6.2-6.8) 10	6.1 (5.5-6.8) 5
	DO	5.2 (5.0-5.5) 8	5.1 (4.8-5.4) 10	5.2 (4.8-5.5) 10	5.4 (5.1-5.8) 7	6.6 (5.9-7.3) 10	5.8 (5.4-6.1) 10
	EI	4.7 --- 1	3.8 --- 1	5.1 (4.2-6.1) 3			
	EO	6.3 --- 1	6.6 (1.4-11.7) 3	4.2 --- 1			
	WI	5.2 (4.7-5.6) 10	5.4 (5.1-5.7) 9	4.4 (4.0-4.8) 10			
	WO	5.2 (4.9-5.5) 10	5.1 (4.3-5.8) 10	5.1 (4.4-5.7) 10			
	SP	5.4 (5.0-5.7) 8	5.4 (4.9-6.1) 8	5.0 (4.7-5.3) 9	5.0 (4.6-5.4) 9	6.9 (6.5-7.3) 10	5.9 (5.6-6.2) 10
Counting Error		± 0.4	± 0.4	± 0.4	± 0.3	± 0.4	± 0.4

* Negative confidenc limit.

Table IIi. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species: *Macoma balthica* Element: Mercury Date Collection		8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	.209 (.200-.217) 6	.194 (.188-.200) 24	.274 (.258-289) 14			
	NO	.212 (.196-.228) 10	.178 (.164-.193) 16	.290 (.275-.304) 17	.247 (.236-.258) 27	.327 (.305-.348) 12	.284 (.258-.309) 12
	SI	.223 (.207-.239) 6	.224 (.209-.239) 19	.409 (.383-.435) 17	.255 (.142-.369) 5	.347 (.223-.372) 10	.349 (.312-.385) 7
	SI-D					.363 (.301-.426) 5	
	SO	.181 (.175-.187) 13	.195 (.184-.206) 25	.235 (.209-.261) 14	.268 (.253-.283) 30	.427 (.312-.542) 9	.300 (.278-.322) 12
	SO-D					.344 (.317-.372) 13	.257 (.240-.274) 10
	TI	.183 (.180-.186) 4	.164 (.155-.172) 21	.366 (.346-.386) 18			
	TO	.197 (.134-.260) 3	.160 (.152-.169) 13	.375 (.303-.448) 9			
	DI	.225 (.213-.238) 6	.208 (.183-.233) 7	.344 (.318-.370) 6	.315 (.295-.336) 14	.437 (.417-.456) 11	.517 (.432-.601) 6
	DO	.209 (.190-.228) 7	.174 (.161-.188) 10	.319 (.300-.338) 13	.378 (.300-.457) 6	.328 (.390-.365) 10	.340 (.317-.362) 10
	EI	.233 --- 1	.224 --- 1	.434 (.343-.524) 4			
	EO	.273 --- 1	.227 (.161-.293) 4	.402 --- 1			
	WI	.174 (.163-.184) 12	.202 (.185-.219) 9	.376 (.345-.407) 14			
	WO	.157 (.149-.165) 26	.169 (.153-.184) 14	.296 (.280-.312) 21			
	SP	.243 (.227-.259) 8	.202 (.172-.231) 8	.383 (.360-.405) 19	.335 (.321-.349) 17	.438 (.403-.473) 12	.449 (.419-.480) 12

Table IIIa. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	*Neanthes succinea* Silver	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 VI	28 Mar 74 V	19 Apr 74 VI
Station	NI	0.8 (0.0-1.7) 3	<0.7 --- 5	2.4 (1.0-3.8) 4			
	NO	0.8 (* -2.3) 3	≤0.7 (* -1.5) 5	1.0 (0.4-1.4) 5	<0.7 --- 5	1.4 (0.6-2.3) 3	0.8 (0.5-1.2) 5
	SI	1.4 (1.2-1.6) 5	1.9 (0.4-3.4) 5	1.3 (0.6-2.1) 4	<0.7 --- 1		<0.6 --- 5
	SO	0.9 (0.6-1.2) 6	1.1 (0.8-1.4) 7	1.1 (0.6-1.5) 7	<0.7 --- 4	2.1 --- 1	<0.6 --- 5
	SO-D					1.6 (1.0-2.2) 3	
	TI	0.8 (0.3-1.3) 4	0.9 (0.0-1.8) 4	0.8 (0.2-1.4) 5			
	TO	1.5 --- 2	1.0 (0.6-1.3) 4	1.3 (0.7-1.9) 3			
	DI	0.7 --- 1	0.8 (0.2-1.3) 4	2.5 --- 2	1.0 (0.4-1.6) 5	2.0 (0.6-3.5) 3	1.8 (1.3-2.3) 4
	DO	0.8 (0.7-0.9) 3	1.5 --- 2	<0.7 --- 2	0.8 (* -2.4) 5	1.6 (0.4-2.8) 5	1.4 (0.9-2.0) 5
	EI	0.7 --- 2	≤0.7 (0.3-1.1) 3	<0.7 --- 2			
	EO	<0.5 --- 2	0.9 (* -2.2) 3	<0.7 --- 2			
	WI	0.8 --- 2	1.5 (1.0-1.9) 5	<0.7 --- 3			
	WO	<0.5 --- 1	<0.7 --- 4	<0.7 --- 2			
	SP	1.5 (0.6-2.4) 5	1.2 (0.8-1.6) 5	1.7 (0.8-2.6) 4	1.0 (0.3-1.6) 5	1.9 (0.5-3.2) 3	2.1 (1.5-2.7) 4
Counting Error		± 0.5	± 0.7	± 0.7	± 0.7	± 0.7	± 0.6

* Negative confidence limit.

Table IIIb. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Neanthes succinea Arsenic	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	5.8 (4.1-7.4) 3	5.9 (4.6-7.2) 6	3.5 (2.1-5.0) 4			
	NO	6.9 (5.1-8.7) 3	5.6 (4.1-7.0) 6	6.1 (5.3-6.8) 7	5.6 (5.1-6.2) 10	5.6 (3.7-7.5) 3	5.2 (4.7-5.8) 4
	SI	4.8 (3.2-6.3) 5	5.3 (4.6-5.9) 6	3.5 (1.7-5.4) 4	4.0 (2.7-5.2) 5	3.7 (3.0-4.4) 10	5.9 (5.1-6.8) 8
	SO	5.9 (5.2-6.6) 6	7.2 (6.0-8.4) 7	6.7 (5.9-7.4) 7	3.3 (2.8-3.9) 5	4.3 --- 1	5.3 (4.7-5.8) 9
	SO-D					6.0 (3.9-8.0) 3	
	TI	6.3 (4.9-7.6) 4	7.5 (6.7-8.3) 4	3.5 (2.8-4.1) 6			
	TO	5.4 (0.2-10.6) 2	8.1 (7.2-9.0) 4	4.9 (3.4-6.4) 3			
	DI	4.2 --- 1	4.3 (3.5-5.0) 4	4.0 (3.2-4.7) 2	4.8 (3.8-5.7) 6	3.9 (* -8.3) 3	4.2 (2.6-5.9) 4
	DO	6.8 (6.2-7.4) 3	13.2 (1.4-2.5) 2	6.4 (4.7-8.2) 4	5.2 (3.6-6.9) 6	7.5 (6.4-8.5) 3	4.5 (3.9-5.1) 8
	RI	5.2 (0.0-10.5) 2	7.4 (6.6-8.3) 3	5.2 (3.7-6.6) 2			
	RO	8.7 (7.8-9.6) 2	5.4 (4.7-6.2) 3	4.6 --- 2			
	WI	4.5 --- 2	4.1 (3.3-4.8) 7	4.5 (1.9-7.1) 4			
	WO	5.6 --- 1	7.3 (6.2-8.4) 7	4.9 (4.3-5.5) 2			
	SP	4.4 (3.3-5.0) 5	4.9 (3.5-6.3) 6	5.5 (4.9-6.0) 10	6.0 (5.2-6.8) 7	6.0 (3.6-8.5) 3	6.3 (4.4-8.1) 4
Counting Error		± 0.6	± 0.7	± 0.6	± 0.5	± 0.6	± 0.6

* Negative confidence limit.

Table IIIc. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Neanthes succinea Cadmium	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	1.6 (1.0-2.2) 3	1.4 (0.6-2.2) 5	1.7 (1.1-2.2) 4			
	NO	1.9 (1.0-2.8) 3	1.5 (1.0-2.0) 5	1.5 (1.3-1.8) 5	1.5 (0.7-2.3) 5	2.9 (2.5-3.3) 3	1.5 (1.0-2.0) 5
	SI	1.6 (1.0-2.8) 5	1.0 (1.0-2.0) 5	1.9 (1.3-1.8) 4	1.2 --- 1		1.5 (1.1-1.9) 5
	SO	1.0 (0.6-1.4) 6	1.0 (0.5-1.4) 7	1.4 (0.7-2.1) 7	1.2 (0.8-1.6) 4	2.1 --- 1	<0.7 --- 5
	SO-D					1.4 --- 2	
	TI	1.3 (1.0-1.7) 4	1.7 (1.0-2.[illegible] 4	1.4 (0.6-2.2) 5			
	TO	1.1 --- 2	1.5 (1.1-1.8) 4	1.0 (0.0-2.0) 3			
	DI	2.0 --- 1	2.3 (0.6-2.0) 4	2.5 --- 2	3.2 (2.8-3.7) 5	5.3 (2.7-7.8) 3	3.0 (1.7-4.3) 4
	DO	2.1 (1.6-2.5) 3	2.6 --- 2	1.1 --- 2	1.9 (0.6-3.2) 5	3.1 (2.3-4.0) 5	1.4 (1.1-1.7) 5
	EI	2.2 --- 2	2.4 (1.8-3.1) 3	4.0 --- 2			
	EO	2.6 --- 2	1.9 (0.9-3.0) 3	1.0 --- 2			
	WI	2.8 --- 2	1.8 (1.6-2.1) 5	1.7 (0.4-3.0) 3			
	WO	2.2 --- 1	<0.7 --- 4	<0.7 --- 2			
	SP	1.2 (0.8-1.7) 5	1.4 (1.0-1.8) 5	2.0 (0.5-3.6) 4	1.9 (1.0-2.7) 5	3.6 (2.7-4.5) 3	1.6 (1.3-1.9) 4
Counting Error		± 0.5	± 0.7	± 0.7	± 0.7	± 0.8	± 0.7

* Negative confidence limit.

Table IIId. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Neanthes succinea Copper	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	26.0 (17.1-34.9) 3	23.9 (20.7-27.0) 6	29.4 (27.6-31.2) 4			
	NO	20.2 (18.1-22.3) 3	20.3 (19.1-21.6) 6	24.8 (22.4-27.0) 7	26.9 (25.0-28.9) 10	35.9 (31.7-40.1) 3	35.0 (31.2-38.6) 4
	SI	31.4 (23.6-39.2) 5	28.4 (21.8-35.0) 6	27.6 (19.8-35.5) 4	28.8 (24.7-32.9) 5	39.1 (35.3-42.9) 10	43.1 (41.1-45.1) 8
	SO	38.7 (34.9-42.5) 6	42.1 (37.9-46.4) 7	33.8 (28.6-38.8) 7	39.0 (31.2-46.7) 5	59.9 --- 1	51.8 (46.2-57.3) 9
	SO-D					65.4 (56.4-74.5) 3	
	YI	25.0 (21.2-28.8) 4	37.7 (25.7-49.7) 4	25.2 (22.2-28.2) 6			
	YO	20.2 (10.5-29.9) 2	27.0 (21.0-33.0) 4	21.4 (16.9-26.0) 3			
	DI	18.1 — 1	24.2 (18.5-30.0) 4	33.8 (29.0-38.6) 2	32.4 (30.3-34.5) 6	35.6 (19.7-51.6) 3	45.8 (32.8-58.9) 4
	DO	26.0 (23.7-28.3) 3	30.7 --- 2	26.6 (19.0-34.2) 4	25.2 (21.7-28.7) 6	41.7 (36.9-46.5) 3	29.3 (26.2-32.5) 8
	EI	21.8 (18.8-24.9) 2	19.0 (16.5-21.4) 3	21.1 (18.6-23.6) 2			
	EO	15.2 (9.1-21.3) 2	17.0 (14.1-20.0) 3	16.4 (16.3-16.5) 2			
	WI	23.3 --- 2	22.3 (18.4-26.1) 7	24.0 (20.2-28.0) 4			
	WO	20.7 --- 1	17.7 (14.7-20.7) 7	24.9 (22.7-27.2) 2			
	SP	29.5 (18.5-40.4) 5	16.7 (15.0-18.4) 6	23.9 (21.1-26.8) 10	47.4 (39.2-55.7) 7	41.0 (32.8-49.3) 3	58.2 (48.2-68.1) 4
Counting Error		± 1.0	± 1.3	± 1.2	± 1.2	± 1.5	± 1.3

* Negative confidence limit.

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Table IIIe. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Neanthes succinea Nickel	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	9.6 (6.9-12.2) 3	9.0 (7.9-10.0) 6	11.8 (7.2-16.3) 4			
	NO	20.2 (18.8-22.3) 3	9.4 (7.7-11.0) 6	17.4 (15.4-19.5) 7	9.0 (8.0-10.0) 8	7.2 (2.7-11.7) 3	7.0 (3.7-10.4) 4
	SI	22.5 (16.8-28.1) 4	10.1 (7.9-12.3) 5	9.3 (2.6-16.0) 4	5.8 (4.5-7.0) 5	6.6 (5.4-7.9) 10	28.6 (19.4-36.5) 8
	SO	4.6 (3.4-5.8) 6	14.4 (9.5-19.3) 5	3.9 (2.1-5.8) 7	6.2 (5.1-7.2) 5	6.8 --- 1	7.4 (4.4-10.1) 9
	SO-D					6.6 (4.2-9.0) 3	
	TI	18.0 (9.4-26.6) 3	12.4 (9.9-14.8) 4	8.7 (6.4-11.1) 6			
	TO	21.2 (5.3-37.0) 2	20.5 (14.1-26.9) 4	8.4 (2.6-14.3) 3			
	DI	11.0 --- 1	4.5 (2.2-6.8) 4	11.7 --- 2	12.1 (10.7-13.6) 6	14.6 (3.4-25.8) 3	9.4 (5.2-13.5) 4
	DO	17.1 (14.1-20.1) 3	13.4 (2.2-24.6) 2	14.5 (5.8-23.2) 4	10.0 (6.8-13.2) 6	8.8 (0.0-17.7) 3	8.7 (5.3-12.2) 4
	EI	4.3 --- 2	6.8 (5.9-7.8) 3	9.8 (7.8-12.0) 2			
	EO	5.6 (3.9-7.4) 2	15.3 (7.9-22.7) 3	24.1 (18.1-30.7) 2			
	WI	11.3 --- 2	7.0 (4.3-9.8) 7	8.9 (7.5-10.3) 4			
	WO	4.6 --- 1	5.1 (3.5-6.6) 7	14.8 (2.8-26.9) 2			
	SP	23.8 (8.1-39.6) 5	3.5 (2.4-4.6) 6	10.7 (7.9-13.5) 10	11.2 (8.5-14.0) 7	8.4 (2.9-13.8) 3	12.7 (8.8-16.6) 4
Counting Error		± 1.0	± 1.1	± 1.1	± 1.0	± 1.1	± 1.0

* Negative confidence limit.

Table IIIf. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	*Neanthes succinea* Lead	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	4.0 (2.0-6.1) 3	2.6 (1.0-4.3) 5	4.5 (2.6-6.3) 4			
	NO	2.6 (1.7-3.6) 3	3.2 (1.5-4.9) 5	4.3 (2.3-6.3) 7	<1.3 --- 8	1.9 (1.2-2.5) 3	2.2 (0.7-3.6) 3
	SI	9.3 (5.7-12.9) 5	5.7 (4.2-7.2) 6	5.6 (2.8-8.5) 4	2.2 (1.7-2.8) 4	4.5 (3.2-5.9) 10	7.0 (5.6-8.5) 8
	SO	1.4 (0.8-2.0) 6	6.9 (4.2-9.6) 7	<1.3 --- 6	≤1.3 --- 4	2.1 --- 1	2.0 (1.0-3.0) 9
	SO-D					2.7 (* -7.0) 3	
	TI	1.8 (0.7-2.8) 4	3.1 (0.6-5.6) 4	3.7 (2.7-4.7) 6			
	TO	2.4 (0.6-4.3) 2	5.2 (2.6-7.9) 4	1.9 (* -3.9) 3			
	DI	3.2 --- 1	3.2 (1.0-5.3) 4	4.1 --- 2	2.0 (1.2-2.8) 6	5.4 (1.0-9.8) 3	3.7 (2.2-5.2) 4
	DO	6.8 (5.8-8.5) 3	2.6 --- 2	3.9 (2.2-5.6) 4	2.1 (1.0-3.2) 5	2.8 (1.5-4.2) 3	2.6 (1.6-3.6) 8
	EI	2.8 --- 2	<1.5 --- 3	3.1 --- 2			
	EO	<1.2 --- 2	1.8 (0.1-3.4) 3	3.7 --- 2			
	WI	3.8 --- 2	2.4 (1.6-3.1) 7	2.5 (1.0-4.0) 4			
	WO	2.7 --- 1	<1.5 --- 7	3.3 --- 2			
	SP	1.9 (1.2-2.6) 5	2.0 (1.3-2.6) 5	3.3 (2.5-4.0) 9	3.3 (2.0-4.6) 6	<1.4 --- 3	3.6 (1.4-5.7) 4
Counting Error		± 1.2	± 1.5	± 1.2	± 1.2	± 1.4	± 1.1

* Negative confidence limit.

Table IIIg. Mean concentration in ppm dry weight, 95%confidence limits and sample size vs. collection schedule.

Species Element Date Collection	*Neanthes succinea* Zinc	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	334 (160-400) 3	558 (344-774) 6	745 (389-1100) 4			
	NO	233 (180-288) 3	245 (192-299) 6	261 (175-347) 7	282 (211-352) 10	343 (120-566) 3	243 (213-273) 4
	SI	327 (241-414) 5	557 (436-678) 6	449 (182-715) 4	368 (282-455) 5	767 (619-915) 10	388 (313-464) 8
	SO	155 (104-206) 5	259 (167-352) 7	187 (137-236) 7	209 (78-340) 5	270 --- 1	224 (142-305) 9
	SO-D				•	247 (118-376) 3	
	TI	309 (217-402) 4	299 (157-441) 4	416 (332-500) 6			
	TO	426 --- 2	311 (232-391) 4	239 (127-351) 3			
	DI	377 --- 1	379 (316-442) 4	427 (296-559) 2	340 (235-445) 6	792 (540-1045) 3	529 (446-612) 4
	DO	179 (138-221) 3	330 --- 2	269 (100-437) 4	284 (202-365) 6	258 (135-381) 3	320 (266-374) 8
	EI	460 --- 2	359 (197-520) 3	479 (406-552) 2			
	EO	133 (57-208) 2	332 (121-542) 3	274 (268-280) 2			
	WI	458 (242-673) 2	417 (360-474) 7	369 (162-577) 4			
	WO	193 --- 1	238 (198-278) 7	234 (130-337) 2			
	EP	218 (109-327) 5	306 (269-343) 6	322 (247-396) 10	369 (226-511) 7	492 (214-770) 3	293 (186-400) 4
Counting Error		± 3	± 3	± 3	± 3	± 4	± 3

• Negative confidence limit.

Table IIIh. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Neanthes succinea Selenium	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	6.8 (6.1-7.5) 3	7.1 (5.2-8.0) 6	5.9 (4.7-7.0) 4			
	NO	6.2 (5.6-6.8) 3	6.5 (5.8-7.2) 6	5.8 (4.5-7.2) 7	7.0 (6.3-7.6) 10	6.3 (4.4-8.2) 3	6.8 (6.0-7.6) 4
	SI	5.1 (4.1-6.1) 5	6.7 (5.3-8.2) 6	5.4 (3.6-7.5) 4	6.2 (5.3-7.1) 5	6.8 (6.0-7.7) 10	6.0 (4.5-7.4) 8
	SO	5.3 (3.8-6.8) 6	7.1 (6.0-8.1) 7	7.1 (6.2-8.0) 7	5.6 (4.2-7.0) 5	5.4 --- 1	6.0 (5.6-6.3) 9
	SO-D					7.9 (6.5-9.3) 3	
	TI	7.9 (6.9-9.0) 4	8.6 (7.2-10.1) 4	5.2 (4.1-6.4) 6			
	TO	7.4 --- 2	7.4 (6.4-8.3) 4	6.6 (6.4-6.8) 3			
	DI	6.4 --- 1	8.8 (7.3-10.4) 4	6.7 --- 2	7.0 (6.2-7.7) 6	7.8 (2.9-12.6) 3	7.1 (5.2-9.0) 4
	DO	6.0 (4.8-7.3) 3	12.0 --- 2	5.7 (4.6-6.8) 4	6.0 (5.0-6.8) 6	8.8 (6.4-11.1) 3	6.9 (6.2-7.5) 8
	EI	6.2 --- 2	8.7 (7.6-9.8) 3	7.1 --- 2			
	EO	6.4 --- 2	6.8 (3.4-10.3) 3	4.6 --- 2			
	WI	5.9 --- 2	7.1 (5.8-8.4) 7	5.8 (3.4-8.3) 4			
	WO	4.8 --- 1	6.2 (5.4-6.9) 7	4.9 --- 2			
	SP	3.8 (2.9-4.6) 5	5.8 (4.2-7.4) 6	6.7 (6.0-7.3) 10	5.7 (4.4-7.0) 7	7.9 (4.6-11.2) 3	5.6 (3.3-7.8) 4
Counting Error		± 0.6	± 0.7	± 0.6	± 0.6	± 0.7	± 0.5

* Negative confidence limit.

Table IIIi. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	*Neanthes succinea* Mercury	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	.230 (.208-.252) 3	.181 (.167-.196) 7	.243 (.211-.276) 5			
	NO	.170 (.138-.203) 3	.150 (.136-.163) 8	.194 (.183-.205) 6	.182 (.172-.192) 10	.265 (.216-.314) 4	.231 (.164-.298) 5
	SI	.189 (.152-.225) 5	.153 (.143-.163) 7	.204 (.149-.259) 3	.180 (.174-.186) 5	.259 (.245-.273) 10	.253 (.239-.268) 8
	SO	.107 (.097-.117) 3	.142 (.117-167) 6	.197 (.173-.221) 8	.142 (.120-.164) 5	.208 (.175-.242) 3	.184 (.168-.201) 6
	TI	.140 (.114-.167) 5	.182 (.142-.222) 4	.209 (.178-.240) 4			
	TO	.170 (.148-.191) 2	.204 (.154-.255) 4	.167 (.137-.196) 3			
	DI	.196 (.170-.322) 2	.254 (.222-.285) 5	.260 (.233-.287) 2	.247 (.230-.264) 6	.514 (.328-.700) 3	.339 (.287-.391) 4
	DO	.231 (.202-.252) 3	.196 (.179-.213) 2	.180 (.098-.262) 3	.192 (.184-.200) 6	.264 (.211-.317) 3	.226 (.212-.239) 9
	EI	.197 (.169-.226) 3	.196 (.155-.238) 4	.262 (.244-.279) 2			
	EO	.153 (.136-.170) 2	.139 (.109-.170) 3	.198 (.171-.225) 4			
	WI	.151 (.143-.174) 2	.146 (.129-.164) 9	.200 (.177-.222) 4			
	WO	.121 ---- 1	.147 (.130-.163) 9	.259 ---- 1			
	SP	.158 (.129-.186) 6	.142 (.130-.154) 6	.189 (.177-.200) 11	.225 (.174-.276) 7	.272 (.255-.289) 4	.230 (.219-.241) 8

Table IVa. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	<u>Ampelisca</u> <u>milleri</u> Silver	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	MI	1.1 (0.5-1.8) 4	1.0 (0.8-1.2) 3	--- --- ---	✝		
	MO	0.8 (0.2-1.4) 5	1.0 (0.6-1.5) 5	--- --- ---			
	SI	1.0 (0.6-1.4) 5	0.9 (0.7-1.2) 2	1.0 --- 1			
	SO	--- --- ---	1.2 --- 1	--- --- ---			
	TI	0.9 (0.7-1.1) 4	0.8 (0.6-1.1) 5	1.1 --- 2			
	TO	0.9 (0.5-1.2) 3	0.7 (0.4-1.4) 5	1.1 (0.7-1.5) 4			
	DI	0.6 (0.3-0.8) 5	0.4 (0.0-0.9) 5	0.9 --- 1			
	DO	0.9 (0.5-1.3) 5	1.2 (0.4-1.9) 5	1.4 (0.9-1.9) 5			
	EI	1.1 (0.7-1.4) 5	0.8 (0.5-1.0) 5	1.3 (0.8-1.8) 5			
	EO	0.6 (0.2-1.0) 5	0.8 0.3-1.3) 5	1.4 (1.2-1.7) 5			
	WI	0.5 (0.2-0.8) 5	0.8 (0.3-1.3) 5	1.0 --- 2			
	WO	0.8 (0.4-1.1) 5	0.7 (0.6-0.9) 6	1.2 --- 2			
	SP	0.7 (0.0-1.5) 5	1.0 (0.8-1.2) 5	1.0 (0.4-1.6) 4			
Counting Error		± 0.5	± 0.5	± 0.5			

✝ No specimens present after Collection III (see population data).

Table IVb. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	*Ampelisca milleri* Arsenic	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	2.8 (1.0-4.6) 4	3.7 (2.4-4.9) 3	--- --- ---	†		
	NO	2.3 (1.8-2.8) 9	3.6 (3.2-4.0) 10	--- --- ---			
	SI	4.7 (4.1-5.2) 9	3.8 --- 2	5.1 --- 1			
	SO	--- --- ---	4.0 --- 2	--- --- ---			
	TI	4.2 (2.6-5.7) 4	3.9 (3.5-4.4) 5	5.9 --- 2			
	TO	4.6 (4.1-5.1) 3	4.0 (3.5-4.5) 10	5.7 (3.8-7.6) 4			
	DI	4.2 (3.8-4.5) 10	3.2 (3.5-4.5) 10	4.0 --- 1			
	DO	3.8 (3.2-4.3) 10	4.0 (3.6-4.3) 7	5.2 (4.5-5.8) 5			
	EI	4.1 (3.6-4.5) 10	4.0 (3.7-4.3) 10	6.4 (5.9-6.9) 10			
	EO	4.6 (4.4-4.8) 5	3.8 (3.5-4.1) 10	5.4 (4.9-6.0) 10			
	WI	5.8 (5.0-6.6) 9	4.3 (3.9-4.8) 10	6.3 --- 2			
	WO	4.2 (3.6-4.7) 10	4.1 (3.6-4.6) 10	5.8 --- 2			
	SP	3.9 (3.0-4.8) 5	3.9 (3.5-4.3) 9	4.6 (3.1-6.2) 4			
Counting Error		± 0.6	± 0.5	± 0.7			

† No specimens present after Collection III (see population data).

Table IVc. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Ampelisca milleri Cadmium	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	2.6 (1.8-3.1) 4	2.2 (1.5-3.0) 3	--- --- ---	†		
	NO	2.8 (1.7-3.9) 5	2.7 (2.3-3.0) 5	--- --- ---			
	SI	3.4 (2.0-2.8) 5	1.9 --- 2	1.2 --- 1			
	SO	--- --- ---	3.0 --- 1	--- --- ---			
	TI	2.0 (1.6-2.4) 4	1.9 (1.6-2.1) 5	1.7 --- 2			
	TO	2.8 (2.3-3.3) 3	2.4 (1.9-3.0) 5	1.6 (1.3-1.9) 4			
	DI	2.5 (2.1-3.0) 5	2.4 (1.9-3.0) 5	2.8 --- 1			
	DO	2.5 (2.2-2.9) 5	2.7 (2.4-3.0) 5	2.9 (2.5-3.2) 5			
	RI	2.1 (1.7-2.4) 5	2.4 (1.9-3.0) 5	2.5 (2.3-2.7) 5			
	RO	2.3 (2.0-2.6) 5	2.7 (2.3-3.1) 5	2.2 (1.9-2.5) 5			
	WI	1.8 (1.6-2.1) 5	1.6 (1.2-1.9) 5	2.3 --- 2			
	WO	2.4 (1.8-3.0) 5	2.8 (2.4-3.2) 6	2.6 --- 2			
	SP	1.8 (1.6-2.0) 5	2.3 (2.0-2.6) 5	2.0 (1.7-2.3) 4			
Counting Error		± 0.5	± 0.5	± 0.5			

† No specimens present after Collection III (see population data).

Table IVd. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	*Ampelisca milleri* Copper	8 Oct 73 I	22 Oct 74 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	56.5 (47.1-66.0) 4	74.3 (62.0-86.7) 3	--- --- ---	†		
	NO	50.0 (42.1-57.9) 10	55.6 (52.0-59.3) 10	--- --- ---			
	SI	83.7 (74.9-92.5) 9	75.4 --- 2	47.2 --- 1			
	SO	--- --- ---	71.9 --- 1	--- --- ---			
	TI	65.3 (56.5-74.1) 4	76.2 (70.4-82.1) 5	44.4 --- 2			
	TO	87.8 (61.6-114) 3	67.9 (64.6-71.2) 10	50.6 (46.5-54.8) 3			
	DI	52.4 (44.8-60.0) 10	69.7 (62.6-76.8) 10	66.5 --- 1			
	DO	43.4 (40.1-46.8) 10	72.2 (68.2-76.2) 7	65.0 (62.3-67.7) 5			
	EI	41.2 (40.1-42.0) 10	64.7 (59.7-69.8) 10	65.7 (63.6-67.7) 10			
	EO	37.9 (35.7-40.0) 5	68.3 (65.0-71.6) 10	59.7 (57.7-61.7) 10			
	WI	76.0 (71.5-80.5) 9	68.0 (66.0-70.0) 10	64.1 --- 2			
	WO	52.9 (51.3-54.4) 10	74.6 (71.0-78.3) 11	69.8 --- 2			
	SP	39.8 (33.8-45.7) 5	64.4 (61.5-67.3) 9	44.8 (43.3-46.3) 4			
Counting Error		± 1.5	± 1.7	± 1.3			

† No specimens present after Collection III (see population data).

Table IVe. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	*Ampelisca milleri* Nickel	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	8.2 (4.5-12.0) 4	4.9 (3.6-6.2) 3	--- --- ---	†		
	NO	7.8 (6.7-8.8) 10	7.5 (7.0-8.0) 10	--- --- ---			
	SI	8.1 (7.1-9.1) 9	4.6 (1.7-7.4) 2	16.1 --- 1			
	SO	--- --- ---	3.7 --- 1	--- --- ---			
	TI	10.6 (8.1-13.2) 4	4.0 (2.7-5.2) 5	20.2 --- 2			
	TO	11.5 (9.1-13.9) 7	5.0 (4.4-5.6) 10	18.4 (16.3-20.5) 4			
	DI	10.6 (5.5-15.6) 10	4.5 (3.9-5.1) 10	10.9 --- 1			
	DO	9.7 (8.6-10.7) 10	3.6 (3.0-4.3) 7	15.6 (14.9-16.2) 5			
	EI	7.4 (6.9-7.9) 10	5.6 (5.2-6.1) 10	20.8 (19.2-22.3) 10			
	EO	4.2 (3.5-4.9) 5	5.0 (4.6-5.3) 10	17.7 (16.6-18.7) 10			
	WI	10.1 (9.2-11.0) 9	5.4 (4.9-5.9) 10	12.9 --- 2			
	WO	4.3 (3.7-4.8) 10	6.5 (6.2-7.2) 11	19.3 --- 2			
	SP	9.1 (7.7-10.4) 5	5.4 (4.8-6.0) 9	13.2 (11.1-15.2) 4			
Counting Error		± 1.0	± 0.9	± 1.2			

† No specimens present after Collection III (see population data).

Table IVf. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	*Ampelisca milleri* Lead	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	7.6 (0.0-15.1) 4	<1.4 --- 3	--- --- ---	†		
	NO	2.7 (1.5-3.8) 9	<1.4 --- 10	--- --- ---			
	SI	4.5 (2.6-6.5) 9	<1.4 --- 2	16.5 --- 1			
	SO	--- --- ---	2.1 --- 1	--- --- ---			
	TI	3.1 (0.9-5.3) 4	<1.4 --- 5	5.8 --- 2			
	TO	3.4 (2.8-3.9) 3	<1.4 --- 10	14.4 (1 - 28.0)			
	DI	1.4 (0.2-2.5) 10	<1.4 --- 10	3.0 --- 1			
	DO	1.0 (0.1-1.9) 10	<1.4 --- 7	1.5 (0.2-2.8) 5			
	DI	0.6 (0.0-1.4) 10	<1.4 --- 10	5.5 (4.7-6.2) 10			
	EO	1.4 --- 5	<1.4 --- 10	4.2 (2.9-5.5) 10			
	WI	1.5 (0.5-2.5 9	<1.4 --- 10	1.6 --- 2			
	WO	<1.4 --- 10	<1.4 --- 9	3.9 --- 2			
	SP	0.6 (0.0-2.3) 5	<1.4 --- 9	1.4 (0.0-3.2) 4			
Counting Error		± 1.5	± 1.4	± 1.5			

† No specimens present after Collection III (see population data).

Table IVg. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Ampelisca milleri Zinc	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	65.5 (59.0-71.9) 4	65.1 (62.0-68.2) 3	--- --- ---	†		
	NO	64.6 (59.5-69.7) 10	62.1 (60.1-64.1) 10	--- --- ---			
	SI	76.1 (70.1-82.1) 9	62.7 --- 2	71.1 --- 1			
	SO	--- --- ---	64.4 --- 1	--- --- ---			
	TI	80.9 (76.0-85.8) 4	61.5 (56.3-66.7) 5	67.0 --- 2			
	TO	80.7 (68.5-93.0) 3	64.2 (61.5-66.9) 10	94.2 (61.9-127) 4			
	DI	70.4 (67.8-72.9) 10	62.0 (58.5-65.5) 10	70.4 --- 1			
	DO	62.6 (59.6-65.6) 10	61.0 (58.9-63.1) 7	70.8 (68.2-73.4) 5			
	EI	65.8 (64.7-66.8) 10	59.2 (58.0-60.4) 10	76.2 (74.1-78.3) 10			
	EO	65.0 (62.0-68.1) 5	61.8 (60.1-63.6) 10	74.3 (69.5079.0) 10			
	WI	75.6 (72.8-78.3) 9	64.8 (63.6-66.0) 10	70.7 --- 2			
	WO	63.7 (60.8-66.6) 10	64.4 (62.3-66.5) 11	72.6 --- 2			
	SP	62.6 (58.2-67.0) 5	62.5 (59.2-65.8) 9	65.9 (62.3-69.5) 4			
Counting Error		± 1.4	± 1.2	± 1.3			

† No specimens present after Collection III (see population data).

Table IVh. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	*Ampelisca milleri* Selenium	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	NI	2.5 (1.7-3.3) 4	2.5 (1.9-3.1) 3	--- --- ---	†		
	NO	2.7 (2.2-3.1) 10	2.5 (2.3-2.8) 10	--- --- ---			
	SI	2.6 (2.4-2.9) 9	2.5 --- 2	1.9 --- 1			
	SO	--- --- ---	2.6 --- 1	--- --- ---			
	TI	2.7 (2.0-3.5) 4	2.5 (1.8-3.1) 5	1.8 --- 2			
	TO	3.0 (2.0-4.1) 3	2.7 (2.3-3.1) 10	2.1 (1.6-2.7) 4			
	DI	3.0 (2.7-3.3) 10	2.7 (2.4-3.0) 10	2.3 --- 1			
	DO	2.2 (1.9-2.5) 10	2.7 (2.4-3.0) 7	2.6 (2.3-2.9) 5			
	EI	2.5 (2.2-2.8) 10	2.7 (2.4-2.6) 10	2.3 (2.1-2.6) 10			
	EO	2.9 (2.6-3.3) 5	2.9 (2.6-3.1) 10	2.6 (2.4-2.9) 10			
	WI	2.8 (2.5-3.1) 9	2.7 (2.5-2.8) 10	2.2 --- 2			
	WO	3.0 (2.7-3.3) 10	2.6 (2.5-2.8) 11	2.5 --- 2			
	SP	2.3 (1.8-2.8) 5	2.4 (2.2-2.6) 9	2.1 (1.0-3.2) 4			
Counting Error		± 0.6	± 0.5	± 0.5			

† No specimens present after Collection III (see population data).

Table IVi. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	*Ampelisca milleri* Mercury	8 Oct 73 I	22 Oct 73 II	22 Nov 73 III	11 Feb 74 IV	28 Mar 74 V	19 Apr 74 VI
Station	MI	.103 (.100-.105)	.118 (.111-.125) 9	--- --- ---	†		
	MO	.091 (.085-.097) 13	.101 (.095-.107) 18	.217 --- 1			
	SI	.104 (.072-.169) 9	.082 (.074-.089) 2	.637 --- 1			
	SO	--- --- ---	.088 (.075-.100) 3	.410 --- 1			
	TI	.100 (.094-.107) 4	.289 (.277-.303) 5	.165 (.159-.173) 2			
	TO	.101 (.094-.113) 3	.092 (.080-.103) 13	.200 (.177-.215) 4			
	DI	.104 (.098-.110) 13	.079 (.074-.084) 15	.152 (.147-.157) 3			
	DO	.089 (.086-.092) 10	.204 (.192-.216) 7	.152 (.137-.167) 5			
	EI	.091 (.088-.095) 15	.245 (.237-.254) 16	.208 (.196-.220) 11			
	EO	.087 (.079-.095) 5	.144 (.137-.151) 15	.150 (.141-.159) 15			
	WI	.086 (.080-.091) 9	.093 (.086-.101) 20	.170 (.166-.178) 2			
	WO	.087 (.084-.091) 15	.095 (.092-.098) 21	.169 --- 1			
	SP	.078 (.070-.085) 5	.140 (.136-.144) 20	.138 (.127-.149) 4			

† No specimens present after Collection III (see population data).

Table Va. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species	*Ischadium demissum*							
Element	Silver							
Date		15 Oct 73	12 Nov 73	26 Nov 73	12 Feb 74	13 Mar 74	29 Mar 74	28 Apr 74
Collection		I	II	III	IV	V	VI	VII
Station	NVM	0.8 (0.3-1.3) 6	0.8 (0.1-1.5) 5	1.0 (0.7-1.4) 5	0.7 (0.4-1.0) 5	0.5 (0.0-1.1) 5	1.3 (0.0-2.8) 5	0.9 (0.4-1.4) 5
	STM	1.0 (0.3-1.6 5	0.6 (0.0-1.2) 5	0.7 (0.5-1.0) 5	<1.0 --- 5	0.7 (0.1-1.3) 5	1.2 (0.7-1.6) 5	<1.0 --- 5
	OWM	0.6 (0.3-0.9) 4	0.6 (0.1-1.1) 5	0.7 (0.5-1.0) 5	<1.0 --- 5	<1.0 --- 5	0.6 (0.4-0.8) 5	0.8 (0.4-1.1) 5
Counting Error		± 0.5	± 0.5	± 0.5	± 0.6	± 0.5	± 0.5	± 0.5

Table Vb. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	*Ischadium demissum* Arsenic	15 Oct 73 I	12 Nov 73 II	26 Nov 73 III	12 Feb 74 IV	13 Mar 74 V	29 Mar 74 VI	28 Apr 74 VII
Station	NVM	5.3 (4.2-6.3) 10	9.6 (8.3-11.0) 10	8.2 (7.4-8.9) 10	7.1 (6.4-7.8) 10	8.2 (7.2-9.2) 10	8.6 (7.5-9.6) 10	6.3 (5.6-7.1) 10
	STM	7.5 (7.0-8.0) 10	6.7 (5.5-7.9) 10	6.4 (5.6-7.1) 10	6.3 (5.5-7.1) 10	6.1 (5.3-6.9) 10	6.4 (5.9-7.0) 10	6.6 (5.9-7.4) 10
	OWM	6.8 (5.9-7.8) 10	7.5 (6.5-8.6) 10	6.9 (6.2-7.6) 10	6.8 (6.2-7.3) 10	7.2 (6.3-8.2) 10	7.7 (7.1-8.2) 10	6.1 (4.9-7.4) 10
Counting Error		± 0.6	± 0.6	± 0.6	± 0.5	± 0.5	± 0.6	± 0.5

Table Vc. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	<u>Ischadium demissum</u> Cadmium	15 Oct 73 I	12 Nov 73 II	26 Nov 73 III	12 Feb 74 IV	13 Mar 74 V	29 Mar 74 VI	28 Apr 74 VII
Station	NVM	12.3 (3.9-20.6) 6	7.5 (4.3-10.7) 5	13.9 (8.0-19.9) 5	20.9 (10.9-30.9) 5	10.0 (7.0-13.0) 5	20.4 (9.8-31.0) 5	13.7 (1.9-25.6) 5
	STM	14.8 (8.7-20.8) 5	13.0 (11.6-14.4) 5	14.8 (7.8-21.8) 5	11.1 (2.2-20.1) 5	17.1 (7.4-26.7) 5	18.6 (10.4-26.9) 5	17.1 (10.9-23.3) 5
	OWM	14.7 (7.2-22.2) 4	16.3 (4.5-28.8) 5	15.7 (12.6-18.7) 5	7.3 (0.0-15.1) 5	16.4 (13.5-19.3) 5	20.3 (10.0-30.7) 5	13.2 (9.5-16.9) 5
Counting Error		± 0.6	± 0.6	± 0.6	± 0.6	± 0.6	± 0.6	± 0.6

Table Vd. **Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.**

Species	*Ischadium demissum*							
Element	Copper							
Date		15 Oct 73	12 Nov 73	26 Nov 73	12 Feb 74	13 Mar 74	29 Mar 74	28 Apr 74
Collection		I	II	III	IV	V	VI	VII
Station	**NVM**	16.5 (13.4-19.6) 10	18.7 (15.8-21.6) 10	26.1 (23.3-28.8) 10	17.6 (15.5-19.8) 10	23.8 (18.3-29.3) 10	20.6 (15.9-25.3) 10	23.7 (20.2-27.2) 10
	STM	16.7 (13.2-20.1) 10	21.2 (17.7-24.7) 10	25.5 (22.7-28.3) 10	20.4 (16.5-24.3) 10	20.1 (17.0-23.2) 10	26.8 (21.5-32.0) 10	21.8 (17.5-26.2) 10
	OWM	10.9 (9.2-12.6) 10	15.4 (9.7-20.9) 10	19.2 (14.9-23.4) 10	20.2 (17.6-22.8) 10	23.9 (20.5-27.3) 10	22.1 (18.9-25.3) 10	20.4 (16.5-24.3) 10
Counting Error		± 0.9	± 1.0	± 1.0	± 0.9	± 0.9	± 0.9	± 0.9

Table Ve. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Iachadium demissum Nickel	15 Oct 73 I	12 Nov 73 II	26 Nov 73 III	12 Feb 74 IV	13 Mar 74 V	29 Mar 74 VI	28 Apr 74 VII
Station	NVM	1.1 (0.6-1.6) 10	0.8 (0.4-1.3) 10	3.5 (3.0-4.1) 10	3.1 (2.6-3.6) 10	4.0 (3.5-4.4) 10	4.4 (3.9-5.0) 10	4.2 (3.5-4.9) 10
	STM	0.9 (0.5-1.3) 10	1.1 (0.6-1.6) 10	1.5 (0.9-2.2) 10	3.0 (2.7-3.3) 10	3.4 (2.8-4.1) 10	5.1 (3.7-6.5) 10	4.5 (3.4-5.6) 10
	OWM	7.2 (4.0-10.4) 10	0.7 (0.4-0.9) 10	3.8 (3.1-4.4) 10	3.4 (2.8-4.0) 10	4.0 (3.6-4.3) 10	6.7 (2.9-10.5) 10	4.1 (3.2-4.9) 10
Counting Error		± 0.7	± 0.7	± 0.7	± 0.6	± 0.7	± 0.7	± 0.6

Table Vf. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Ischadium demissum Lead	15 Oct 73 I	12 Nov 73 II	26 Nov 73 III	12 Feb 74 IV	13 Mar 74 V	29 Mar 74 VI	28 Apr 74 VII
Station	NWM	2.9 (2.2-3.5) 10	2.4 (2.0-2.8) 10	2.4 (1.7-3.1) 10	2.2 (1.7-2.6) 10	1.8 (1.3-2.2) 10	2.5 (2.0-3.9) 10	2.7 (1.1-4.4) 10
	STM	4.5 (3.4-5.5) 10	5.8 (4.6-6.9) 10	3.6 (2.8-4.5) 10	3.4 (2.6-4.2) 10	4.2 (3.2-5.2) 10	4.4 (3.1-5.7) 10	4.9 (3.2-6.6) 10
	OWH	1.2 (0.7-1.6) 10	1.5 (0.8-2.2) 10	2.1 (1.5-2.7) 10	2.4 (1.9-3.0) 10	1.8 (1.3-2.3) 10	1.6 (0.8-2.5) 10	1.2 (0.7-1.8) 10
Counting Error		± 1.1	± 1.2	± 1.0	± 1.0	± 1.0	± 1.0	± 1.0

Table Vg. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species	*Ischadium demissum*							
Element	Zinc							
Date		15 Oct 73	12 Nov 73	26 Nov 73	12 Feb 74	13 Mar 74	29 Mar 74	28 Apr 74
Collection		I	II	III	IV	V	VI	VII
Station	NVM	61.2 (54.3-68.1) 10	73.8 (66.9-80.6) 10	72.7 (67.8-77.7) 10	71.4 (61.8-81.0) 10	76.4 (71.0-81.7) 10	82.3 (70.8-93.9) 10	75.2 (68.4-82.1) 10
	STM	83.7 (74.1-93.2) 10	79.0 (65.2-92.7) 10	77.7 (74.9-80.5) 10	71.7 (65.3-78.2) 10	77.9 (72.2-83.7) 10	87.9 (74.3-102) 10	86.9 (72.1-102) 10
	CWM	56.6 (52.5-60.7) 10	58.5 (51.1-65.9) 10	66.9 (61.0-72.6) 10	80.4 (72.9-87.8) 10	77.5 (73.0-82.0) 10	73.4 (66.7-80.0) 10	69.6 (61.4-77.8) 10
Counting Error		± 1.3	± 1.3	± 1.3	± 1.2	± 1.2	± 1.2	± 1.2

Table Vh. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	<u>Ischadium demissum</u> Selenium	15 Oct 73 I	12 Nov 73 II	26 Nov 73 III	12 Feb 74 IV	13 Mar 74 V	29 Mar 74 VI	28 Apr 74 VII
Station	NVM	3.9 (3.5-4.4) 10	6.6 (5.8-7.3) 10	5.2 (4.8-5.6) 10	3.9 (3.5-4.3) 10	4.4 (4.1-4.7) 10	5.4 (4.8-5.9) 10	4.0 (3.4-4.5) 10
	STM	6.4 (6.0-6.9) 10	6.8 (5.6-7.9) 10	5.6 (5.1-6.0) 10	4.5 (4.1-4.9) 10	4.9 (4.3-5.4) 10	4.9 (4.4-5.3) 10	4.5 (3.9-5.1) 10
	OWM	5.9 (5.3-6.4) 10	5.4 (4.5-6.3) 10	5.3 (4.9-5.7) 10	6.1 (5.7-6.4) 10	5.6 (5.3-5.9) 10	6.1 (5.2-6.9) 10	4.5 (4.0-5.0) 10
Counting Error		± 0.6	± 0.6	± 0.5	± 0.5	± 0.5	± 0.5	± 0.5

Table VI. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species	<u>Ischadium demissum</u>							
Element	Mercury							
Date		15 Oct 73	12 Nov 73	26 Nov 73	12 Feb 74	13 Mar 74	29 Mar 74	28 Apr 74
Collection		I	II	III	IV	*V*	*VI*	VII
Station	**NVM**	.534 (.417-.651) 25	.249 (.224-.274) 18	.354 (.328-.381) 22	.275 (.253-.298) 15	.297 (.268-.325) 13	.378 (.327-.428) 14	.349 (.319-.379) 15
	STM	.287 (.246-.329) 10	.289 (.254-.325) 15	[illegible]57 (.34[illegible]-.387) 24	.312 (.284-.340) 15	.325 (.291-.359) 15	.385 (.337-.433) 15	.407 (.370-.444) 15
	OWM	.164 (.152-.176) 25	.212 (.193-.230) 25	.225 (.211-.239) 25	.211 (.199-.224) 25	.227 (.207-.247) 15	.263 (.232-.294) 15	.254 (.229-.278) 14

Table VIa. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Native *Mytilus edulis* Silver	15 Oct 73 I	10 Nov 73 II	26 Nov 73 III	21 Dec 73 IV	12 Feb 74 V	13 Mar 74 VI	29 Mar 74 VII	28 Apr 74 VIII
Station	STP	<1.0 --- 10	<1.0 --- 10	<1.0 --- 10	<1.0 --- 5				
	OWP	<1.0 --- 5	<1.0 --- 5	<1.0 --- 5	<1.0 --- 5	<1.0 --- 5	<1.0 --- 5	<1.0 --- 5	<1.0 --- 5
Counting Error		± 0.5	± 0.5	± 0.6	± 0.7	± 0.5	± 0.5	± 0.6	± 0.6

Table VIb. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Native *Mytilus edulis* Arsenic	15 Oct 73 I	10 Nov 73 II	26 Nov 73 III	21 Dec 73 IV	12 Feb 74 V	13 Mar 74 VI	29 Mar 74 VII	28 Apr 74 VIII
Station	STP	6.9 (6.3-7.5) 8	7.3 (6.2-8.4) 10	7.3 (6.6-8.0) 10	7.8 (7.2-8.4) 5				
	OWP	6.0 (5.6-6.4) 10	9.2 (7.4-10.9) 10	7.0 (6.4-7.7) 10	6.9 (6.5-7.3) 10	7.2 (6.0-8.4) 9	9.5 (8.3-10.7) 10		11.1 (9.2-12.9) 9
Counting Error		± 0.5	± 0.6	± 0.6	± 0.5	± 0.5	± 0.5		± 0.7

Table VIc. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species	Native *Mytilus edulis*								
Element	Cadmium								
Date		15 Oct 73	10 Nov 73	26 Nov 73	21 Dec 73	12 Feb 74	13 Mar 74	29 Mar 74	28 Apr 74
Collection		I	II	III	IV	V	VI	VII	VIII
Station	STP	9.7 (8.9-10.6) 10	10.2 (8.3-12.1) 10	4.5 (3.6-5.3) 10	10.9 (9.9-11.9) 5				
	OWP	12.0 (10.4-13.5) 5	14.3 (10.7-17.9) 5	10.8 (8.8-12.9) 5	4.9 (0.0-13.3) 5	19.3 (16.7-21.8) 5	25.4 (18.7-32.0) 5	20.8 (18.4-23.2) 5	25.9 (24.2-27.5) 5
Counting Error		± 0.6	± 0.6	± 0.6	± 0.8	± 0.6	± 0.6	± 0.7	± 0.8

Table VId. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species	Native *Mytilus edulis*								
Element	Copper								
Date		15 Oct 73	10 Nov 73	26 Nov 73	21 Dec 73	12 Feb 74	13 Mar 74	29 Mar 74	28 Apr 74
Collection		I	II	III	IV	V	VI	VII	VIII
Station	STP	10.6 (10.0-11.2) 8	12.9 (12.1-13.7) 10	19.5 (17.4-21.6) 10	17.1 (12.6-21.4) 5				
	OWP	9.5 (8.4-10.5) 10	12.7 (9.8-15.7) 10	13.4 (11.3-15.6) 10	12.1 (10.7-13.5) 10	10.9 (10.5-11.3) 9	30.7 (20.8-40.6) 10		16.5 (13.7-19.3) 9
Counting Error		± 0.8	± 0.8	± 1.1	± 0.8	± 0.8	± 1.0		± 1.1

Table VIe. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Native *Mytilus edulis* Nickel	15 Oct 73 I	10 Nov 73 II	26 Nov 73 III	21 Dec 73 IV	12 Feb 74 V	13 Mar 74 VI	29 Mar 74 VII	28 Apr 74 VIII
Station	STP	21.7 (16.4-27.0) 8	10.5 (7.0-14.0) 10	17.0 (14.4-19.5) 10	16.6 (12.4-20.8) 5				
	OWP	6.9 (4.8-9.0) 10	7.8 (5.2-10.3) 10	10.0 (9.2-10.7) 10	9.3 (8.2-10.4) 10	9.2 (8.6-9.9) 9	11.9 (10.9-13.2) 10		16.6 (12.3-20.8) 10
Counting Error		± 0.7	± 0.9	± 1.1	± 0.9	± 0.8	± 0.9		± 1.2

Table VIf. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Native *Mytilus edulis* Lead	15 Oct 73 I	10 Nov 73 II	26 Nov 73 III	21 Dec 73 IV	12 Feb 74 V	13 Mar 74 VI	29 Mar 74 VII	28 Apr 74 VIII
Station	STP	2.2 (1.3-3.1) 8	7.2 (5.5-9.0) 10	11.8 (8.5-15.1) 10	8.9 (7.1-10.6) 5				
	OWP	1.8 (1.3-2.3) 10	2.4 (1.3-3.5) 10	2.4 (2.0-2.8) 10	2.4 (0.7-4.0) 10	1.9 (1.2-2.6) 9	2.4 (1.4-3.4) 10		2.9 (1.8-4.0) 9
Counting Error		± 1.0	± 1.1	± 1.2	± 1.0	± 0.9	± 0.9		± 1.3

Table VIg. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Native *Mytilus edulis* Zinc	15 Oct 73 I	10 Nov 73 II	26 Nov 73 III	21 Dec 73 IV	12 Feb 74 V	13 Mar 74 VI	29 Mar 74 VII	28 Apr 74 VIII
Station	STP	190 (154-226) 8	193 (156-230) 10	295 (246-344) 10	186 (139-232) 5				
	OWP	151 (120-181) 10	239 (138-339) 10	156 (126-286) 10	166 (144-188) 10	210 (178-241) 9	249 (222-276) 10		239 (161-318) 9
Counting Error		± 2.0	± 2.2	± 2.6	± 1.8	± 2.0	± 1.9		± 2.2

Table 7B. Results of a two-way analysis of variance, without replication, of the results of metal analyses of sediments and invertebrates collected at all stations during the first dredging period. The resultant F ratios are presented for comparisons through time and between stations. The collections and stations tested by two-way analysis of variance are listed under each sample type. The ( ) values are degrees of freedom.

Sample/Collection	(df)	Ag	As	Cd	Cu	Hg	Ni	Pb	Se	Zn
Sediments: Coll. I-IV, All stations.	Coll. (3)	0.02	1.08	3.30'	0.52	1.06"	7.29"	1.64	2.49	0.38
	Stat. (12)	1.46	1.80	1.85	10.07"	9.34"	6.70"	4.93"	0.81	7.26"
	(error) (36)									
Ampelisca milleri: Coll. I-III, Excludes stations NI,NO,SO.	Coll. (2)	N.D.	32.79"	0.39	2.88	4.44'	46.69"	6.90"	13.68"	10.30"
	Stat. (9)		3.16'	1.15	0.74	0.75	0.48	1.71	2.01	1.91
	(error) (18)									
Macoma balthica: Coll. I-III, All stations.	Coll. (2)	25.90"	0.86	1.25	61.63"	93.16"	17.17"	22.62"	1.46	8.09"
	Stat. (12)	1.94	3.49"	1.48	2.32'	3.13"	2.38'	2.07	2.89'	3.13"
	(error) (24)									
Macoma balthica: All collections, Stations NO,SI, SO,DI,DO,SP.	Coll. (5)	15.83"	2.89'	4.05"	19.63"	16.84"	2.22	2.79'	3.27'	11.11"
	Stat. (5)	2.05	10.34"	3.20'	4.18"	3.49'	2.62'	4.09"	3.65'	2.02
	(error) (25)									
Neanthes succinea: Coll. I-III, All stations.	Coll. (2)	N.D.	4.57'	0.65	0.30	9.33"	0.99	0.10	8.93"	2.63
	Stat. (12)		1.93	1.92	4.72"	2.56'	0.99	1.80	1.56	4.86"
	(error) (24)									
Neanthes succinea: All collections, Stations NO,SI, SO,DI,DO,SP.	Coll. (5)	N.D.	0.41	8.26"	8.24"	9.02"	1.76	1.42	3.43'	5.65"
	Stat. (5)		3.18'	6.39"	5.08"	8.40"	0.97	3.48'	2.54	11.36"
	(error) (25)									
Ischalium demissum: Collections I-VII, All stations.	Coll. (6)	N.D.	1.15	1.15	4.88"	0.98	3.04'	0.32	2.01	1.52
	Stat. (2)		2.31	0.15	2.49	8.39"	2.33	32.87"	2.15	5.53'
	(error) (12)									
Mytilus edulis: Transplants, Coll. I-IV, Stations ST,T, D,SP.	Coll. (3)	N.D.	1.04	1.08	2.14	18.91"	2.45	2.49	3.96'	3.81
	Stat. (3)		0.78	1.02	1.43	1.45	1.72	4.22"	0.90	1.60
	(error) (9)									

• (df)=4
' Significant at p=.05
" Significant at p=.01

		(2,12)	(2,18)	(2,20)	(2,24)	(3,9)	(3,36)	(5,25)	(6,12)	(9,18)	(10,20)	(12,24)	(12,36)
F ratios significant at	.05	3.9	3.6	3.5	3.4	3.9	2.8	2.6	3.0	2.5	2.4	2.2	2.0
	.01	6.9	6.0	5.9	5.6	7.0	4.4	3.9	4.8	3.7	3.4	3.0	2.7

(degrees of freedom) (df)

Table VIi. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species	Native *Mytilus edulis*								
Element	Mercury								
Date		15 Oct 73	10 Nov 73	26 Nov 73	21 Dec 73	12 Feb 74	13 Mar 74	29 Mar 74	28 Apr 74
Collection		I	II	III	IV	V	VI	VII	VIII
Station	STP	.234 (.214-2.54) 11	.327 (.296-.358) 20	.411 (.379-.442) 23	.453 (.394-.511) 5				
	OWP	.263 (.236-.290) 24	.422 (.353-.491) 25	.423 (.398-.449) 26	.348 (.328-.367) 19	.453 (.391-.514) 16	.561 (.509-.612) 14	.659 (.600-.718) 8	.742 (.588-.896) 12

Table VIIa. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species / Element / Date / Collection	Transplant *Mytilus edulis* Silver	8 Oct 73 Baseline	26 Jan 74 Baseline	26 Oct 73 I	10 Nov 73 II	23 Nov 73 III	21 Dec 73 IV	12 Feb 74 V	13 Mar 74 VI	29 Mar 74 VII	18 Apr 74 VIII	29 May 74 IX
Station	TB-B1	<0.5 --- 46		---	---	---	---	---	---	---	---	---
	TB-B2		<1.0 --- 10	---	---	---	---	---	---	---	---	---
	TB			<1.0 --- 10	<1.0 --- 9	<1.0 --- 9	<1.0 --- 5	<1.0 --- 5	<1.0 --- 5	---	---	<1.0 --- 5
	MO			---	---	---	---	<1.0 --- 5	---	---	---	---
	ST			<1.0 --- 10	<1.0 --- 16	<0.6 --- 9	<0.7 --- 5	---	---	---	---	---
	SO			---	---	---	---	<1.0 --- 5	<1.0 --- 3	---	---	---
	T			<0.5 --- 5	<0.6 --- 5	<0.6 --- 5	<1.0 --- 5	---	---	---	---	---
	TO			---	---	---	---	<1.0 --- 5	<1.0 --- 2	---	---	---
	D			<1.0 --- 5	<0.6 --- 5	<1.0 --- 5	<1.0 --- 5	<0.5 --- 5	---	---	---	---
	WO			---	---	---	---	---	<1.0 --- 5	0.7 (0.0-2.0) 4	1.1 (0.5-1.7) 5	---
	SP			<0.5 --- 5	<1.0 --- 5	<1.0 --- 5	<1.0 --- 5	<1.0 --- 5	---	---	---	---
Counting Error		± 0.5	± 0.5	± 0.5	± 0.6	± 0.6	± 0.7	± 0.6	± 0.5	± 0.6	± 0.6	± 0.5

Table VIIb. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Transplant *Mytilus edulis* Arsenic	8 Oct 73 Baseline	26 Jan 74 Baseline	26 Oct 73 I	10 Nov 73 II	23 Nov 73 III	21 Dec 73 IV	12 Feb 74 V	13 Mar 74 VI	29 Mar 74 VII	18 Apr 74 VIII	29 May 74 IX
Station	TB-B1	4.7 (4.3-5.1) 46		---	---	---	---	---	---	---	---	---
	TB-B2		5.2 (4.1-6.2) 10	---	---	---	---	---	---	---	---	---
	TB			5.6 (4.9-6.4) 10	6.1 (5.3-6.9) 10	6.3 (5.6-6.9) 10	6.6 (5.9-7.2) 10	8.3 (6.8-9.9) 10	7.1 (6.4-7.8) 10	---	---	6.6 (5.8-7.3) 8
	NO			---	---	---	---	6.0 (5.2-6.9) 10	---	---	---	---
	ST			6.5 (5.8-7.2) 10	7.1 (6.0-8.1) 10	7.3 (6.0-8.6) 10	6.4 (5.1-7.7) 10	6.0 (5.2-6.9) 10	---	---	---	---
	SO			---	---	---	---	6.0 (5.0-7.0) 10	8.1 --- 2	---	---	---
	T			7.5 (6.8-8.1) 10	6.3 (5.7-6.8) 10	7.1 (6.5-7.6) 10	6.2 (5.1-7.3) 10	---	---	---	---	---
	TO			---	---	---	---	6.6 (5.7-7.5) 10	9.9 --- 2	---	---	---
	D			6.0 (4.9-7.1) 10	6.8 (6.1-7.5) 10	6.3 (5.3-7.3) 10	6.5 (5.3-7.6) 10	7.6 (6.4-8.9) 10	---	---	---	---
	NO			---	---	---	---	---	7.3 (6.1-8.4) 9	8.0 (4.4-11.1) 7	7.5 (6.4-8.5) 5	---
	SP			6.4 (5.0-7.8) 10	6.1 (5.2-7.1) 10	7.1 (6.3-7.9) 10	6.4 (5.2-7.6) 10	7.1 (5.9-8.4) 5	---	---	---	---
Counting Error		± 0.5	± 0.5	± 0.5	± 0.6	± 0.6	± 0.5	± 0.5	± 0.5	± 0.6	± 0.7	± 0.6

Table VIIc. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Transplant *Mytilus adulis* Cadmium	8 Oct 73 Baseline	26 Jan 74 Baseline	26 Oct 73 I	10 Nov 73 II	23 Nov 73 III	21 Dec 73 IV	12 Feb 74 V	13 Mar 74 VI	29 Mar 74 VII	18 Apr 74 VIII	29 May 74 IX
Station	TB-B1	2.3 (2.0-2.6) 46		---	---	---	---	---	---	---	---	---
	TB-B2		2.3 (1.7-3.0) 10	---	---	---	---	---	---	---	---	---
	TB			2.2 (1.6-2.7) 10	2.7 (2.1-3.3) 9	3.5 (2.6-4.4) 9	4.6 (2.8-6.5) 5	1.7 (0.3-3.2) 5	2.6 (0.6-4.7) 5	---	---	2.0 (1.5-2.5) 5
	MO			---	---	---	---	3.1 (1.6-4.5) 5	---	---	---	---
	ST			3.3 (2.6-4.0) 10	3.5 (2.9-4.2) 16	3.9 (2.8-5.0) 9	2.2 (1.2-3.3) 5	---	---	---	---	---
	SO			---	---	---	---	2.6 (1.4-3.9) 5	3.8 (1.4-6.2) 3	---	---	---
	T			3.6 (2.8-4.4) 5	3.4 (2.8-4.0) 5	4.9 (3.3-6.5) 5	4.9 (2.5-7.2) 5	---	---	---	---	---
	TO			---	---	---	---	3.1 (2.2-3.9) 5	2.6 --- 2	---	---	---
	D			3.1 (2.1-4.0) 5	4.2 (3.5-4.9) 5	3.7 (1.7-5.7) 5	4.2 (2.2-6.1) 5	6.9 (5.7-8.0) 5	---	---	---	---
	WO			---	---	---	---	---	4.1 (2.5-5.7) 5	5.0 (2.4-7.5) 4	5.6 (4.3-6.8) 5	---
	SP			3.0 (1.5-4.5) 5	4.0 (2.3-5.7) 5	4.0 (3.4-5.4) 5	9.9 (3.3-16.5) 5	6.9 (5.0-8.9) 5	---	---	---	---
Counting Error		± 0.5	± 0.5	± 0.5	± 0.6	± 0.6	± 0.7	± 0.6	± 0.5	± 0.7	± 0.8	± 0.5

Table VIId. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Transplant *Mytilus edulis* Copper	8 Oct 73 Baseline	26 Jan 74 Baseline	26 Oct 73 I	10 Nov 73 II	23 Nov 73 III	21 Dec 73 IV	12 Feb 74 V	13 Mar 74 VI	29 Mar 74 VII	18 Apr 74 VIII	29 May 74 IX
Station	TB-B1	5.7 (5.1-6.3) 46		---	---	---	---	---	---	---	---	---
	TB-B2		6.2 (4.8-7.5) 10	---	---	---	---	---	---	---	---	---
	TS			5.5 (4.3-6.7) 10	8.2 (6.8-9.4) 10	8.3 (7.0-9.6) 10	7.1 (6.4-7.8) 10	9.0 (7.0-11.1) 10	6.3 (5.1-7.6) 10	---	---	5.5 (4.7-6.2) 8
	NO			---	---	---	---	6.3 (4.8-7.9) 9	---	---	---	---
	ST			12.0 (9.7-14.3) 10	13.3 (11.4-15.2) 10	11.7 (10.4-12.4) 10	10.1 (8.9-11.2) 10	---	---	---	---	---
	SO			---	---	---	---	6.0 (3.6-8.4) 10	21.6 (0.0-43.8) 10	---	---	---
	T			11.7 (10.2-13.2) 10	10.0 (8.3-11.7) 10	11.4 (10.4-12.4) 10	10.5 (9.2-11.9) 10	---	---	---	---	---
	TO			---	---	---	---	6.9 (4.2-9.5) 10	24.0 --- 2	---	---	---
	D			10.1 (8.9-11.3) 10	11.5 (9.5-13.5) 10	10.4 (7.0-13.8) 10	8.4 (6.4-10.5) 10	11.4 (10.0-12.8) 10	---	---	---	---
	MO			---	---	---	---	---	9.7 (7.8-11.5) 9	10.2 (5.7-14.7) 7	18.2 (15.3-21.2) 5	---
	SP			14.0 (7.4-20.6) 10	10.4 (8.2-12.6) 10	10.3 (9.3-11.3) 10	10.5 (7.8-13.2) 10	15.4 (11.2-19.6) 5	---	---	---	---
Counting Error		± 0.8	± 0.8	± 0.8	± 0.8	± 0.8	± 0.8	± 0.8	± 0.8	± 1.0	± 1.0	± 1.1

Table VIIe. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species: Transplant *Mytilus edulis* Element: Nickel Date Collection		8 Oct 73 Baseline	26 Jan 74 Baseline	26 Oct 73 I	10 Nov 73 II	23 Nov 73 III	21 Dec 73 IV	12 Feb 74 V	13 Mar 74 VI	29 Mar 74 VII	18 Apr 74 VIII	29 May 74 IX
Station	TB-B1	7.3 (5.0-9.6) 46	–	---	---	---	---	---	---	---	---	---
	TB-B2		3.1 (2.3-4.0) 10	---	---	---	---	---	---	---	---	---
	TB			3.8 (2.0-5.6) 10	5.1 (3.2-6.9) 10	5.4 (4.4-6.4) 10	6.0 (5.4-6.6) 10	7.9 (6.2-9.5) 10	5.1 (4.3-5.9) 10	---	---	5.2 (4.6-5.8) 8
	BO			---	---	---	---	4.9 (2.6-7.1) 9	---	---	---	---
	ST			15.1 (8.9-21.4) 10	7.7 (5.3-10.0 10	8.3 (5.3-11.2) 10	12.1 (9.5-14.6) 10	---	---	---	---	---
	SO			---	---	---	---	5.2 (1.7-8.7) 10	24.9 (0.0-58.4 3	---	---	---
	T			7.6 (6.3-8.9) 10	5.7 (4.4-7.0) 10	10.2 (8.3-12.0) 10	11.6 (9.0-14.1) 10	---	---	---	---	---
	TO			---	---	---	---	6.0 (1.8-10.2) 10	29.1 --- 2	---	---	---
	D			9.2 (6.2-12.2) 10	7.4 (5.6-9.1) 10	7.1 (5.9-8.4) 10	8.1 (6.7-9.5) 10	8.1 (7.1-9.1) 10	---	---	---	---
	WO			---	---	---	---	---	7.8 (5.9-9.7) 9	8.1 (4.4-11.7) 7	18.5 (14.9-22.2) 5	---
	SP			5.7 (3.3-8.2) 10	5.7 (3.2-8.1) 10	8.1 (7.0-9.2) 10	10.9 (8.4-13.5) 10	17.7 (5.8-29.7) 5	---	---	---	---
Counting Error		± 0.8	± 0.8	± 0.8	± 0.8	± 0.8	± 0.9	± 1.0	± 0.8	± 0.8	± 1.0	± 0.8

Table VIIf. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Transplant *Mytilus edulis* Lead	8 Oct 73 Baseline	26 Jan 74 Baseline	26 Oct 73 I	10 Nov 73 II	23 Nov 73 III	21 Dec 73 IV	12 Feb 74 V	13 Mar 74 VI	29 Mar 74 VII	18 Apr 74 VIII	29 May 74 IX
Station	TB-B1	0.9 (0.7-1.2) 46		---	---	---	---	---	---	---	---	---
	TB-B2		<1.0 --- 10	---	---	---	---	---	---	---	---	---
	TB			<1.1 --- 10	3.1 (2.2-4.0) 10	<1.0 --- 10	<1.0 --- 10	<1.0 --- 10	<1.0 --- 10	---	---	---
	BO			---	---	---	---	1.7 (0.0-3.8) 10	---	---	---	---
	ST			1.8 (1.2-2.4) 10	4.0 (2.2-4.0) 10	1.3 (0.6-1.9) 10	2.7 (1.7-3.6) 10	---	---	---	---	---
	SO			---	---	---	---	<1.0 --- 10	3.6 (0.0-10.0) 3	---	---	---
	T			1.6 (0.9-2.3) 10	1.9 (1.5-2.3) 10	1.5 (1.1-2.0) 10	1.8 (1.2-2.4) 10	---	---	---	---	---
	TO			---	---	---	---	<1.0 --- 10	5.5 --- 2	---	---	---
	D			<1.1 --- 10	1.9 (1.4-2.4) 10	<1.0 --- 10	<1.0 --- 10	1.2 (0.7-1.7) 10	---	---	---	---
	BD			---	---	---	---	---	<1.0 --- 9	7.7 (5.9-9.5) 4	2.5 (1.0-4.0) 5	---
	SP			1.3 (1.0-1.6) 10	1.2 (0.6-1.8) 10	1.2 (0.8-1.6) 10	1.3 (0.7-1.8) 10	2.6 (1.1-4.1) 5	---	---	---	---
Counting Error		± 1.0	± 1.0	± 1.1	± 1.1	± 1.0	± 1.0	± 1.0	± 1.0	± 1.1	1.2	± 1.0

Table VIIg. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Transplant *Mytilus edulis* Zinc	8 Oct 73 Baseline	26 Jan 74 Baseline	26 Oct 73 I	10 Nov 73 II	23 Nov 73 III	21 Dec 73 IV	12 Feb 74 V	13 Mar 74 VI	29 Mar 74 VII	18 Apr 74 VIII	29 May 74 IX
Station	TB-B1	120 (101-136) 26		---	---	---	---	---	---	---	---	---
	TB-B2		98.0 (72.8-123) 10	---	---	---	---	---	---	---	---	---
	TB			111 (72.0-150) 10	145 (81.0-208) 10	135 (94.0-177) 10	139 (90.8-188) 10	166 (102-230) 10	151 (116-184) 10	---	---	111 (55.6-166) 10
	NO			---	---	---	---	106 (71.0-140) 10	---	---	---	---
	ST			203 (136-270) 10	213 (145-281) 10	184 (109-259) 10	287 (197-377) 10	---	---	---	---	---
	SO			---	---	---	---	117 (73.0-160) 10	249 (20.0-479) 10	---	---	---
	T			165 (126-204) 10	132 (95.0-169) 10	245 (170-321) 10	199 (121-277) 10	---	---	---	---	---
	TO			---	---	---	---	114 (76.0-151) 10	217 --- 2	---	---	---
	D			178 (127-229) 10	148 (85.0-211) 10	160 (133-187) 10	219 (140-298) 10	301 (228-275) 10	---	---	---	---
	WO			---	---	---	---	---	174 (91.0-258) 9	142 (57.0-226) 7	284 (152-407) 5	---
	SP			178 (91.0262) 10	160 (103-217) 10	236 (164-307) 10	231 (123-340) 10	424 (199-649) 5	---	---	---	---
Counting Error		± 1.8	± 1.8	± 1.8	± 1.8	± 2.0	± 2.2	± 3.3	± 3.5	± 2.2	± 2.2	± 3.0

Table VIIh. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Transplant *Mytilus edulis* Selenium	8 Oct 73 Baseline	26 Jan 74 Baseline	26 Oct 73 I	10 Nov 73 II	23 Nov 73 III	21 Dec 73 IV	12 Feb 74 V	13 Mar 74 VI	29 Mar 74 VII	18 Apr 74 VIII	29 May 74 IX
Station	TB-B1	3.8 (3.5-4.2) 46		---	---	---	---	---	---	---	---	---
	TB-B2		3.4 (2.9-3.8) 10	---	---	---	---	---	---	---	---	---
	TB			4.6 (3.7-5.4) 10	4.6 (4.2-5.0) 10	5.4 (4.1-6.7) 10	5.0 (4.4-5.7) 10	2.9 (2.4-3.4) 10	3.4 (2.5-4.3) 10	---	---	2.8 (2.5-3.1) 8
	MO			---	---	---	---	3.8 (2.6-4.9) 10	---	---	---	---
	ST			4.6 (3.6-5.6) 10	5.4 (4.5-6.3) 10	6.0 (4.9-7.1) 10	4.1 (3.4-4.8) 10	---	---	---	---	---
	SO			---	---	---	---	3.4 (2.8-4.1) 10	2.4 (1.8-3.0) 3	---	---	---
	T			5.4 (4.4-6.4) 10	4.7 (3.9-5.4) 10	6.0 (5.3-6.7) 10	4.1 (3.7-4.8) 10	---	---	---	---	---
	TO			---	---	---	---	4.2 (3.0-5.5) 10	2.7 --- 2	---	---	---
	D			4.3 (3.3-5.4) 10	6.6 (5/2-8.0) 10	5.3 (4.3-6.3) 10	4.3 (3.7-4.8) 10	5.0 (4.4-5.5) 10	---	---	---	---
	WO			---	---	---	---	---	4.9 (3.7-6.0) 9	5.9 (3.2-8.6) 8	3.9 (3.9-4.9) 5	---
	SP			4.2 (3.4-5.1) 10	4.3 (3.6-5.1) 10	5.1 (4.6-5.6) 10	4.3 (3.4-5.1) 10	4.5 (3.1-5.9) 5	---	---	---	---
Counting Error		± 0.5	± 0.5	± 0.5	± 0.5	± 0.5	± 0.5	± 0.4	± 0.5	± 0.5	± 0.5	± 0.4

Table VIIi. Mean concentration in ppm dry weight, 95% confidence limits and sample size vs. collection schedule.

Species Element Date Collection	Transplant *Mytilus edulis* Mercury	8 Oct 73 Baseline	26 Jan 74 Baseline	26 Oct 73 I	10 Nov 73 II	23 Nov 73 III	21 Dec 73 IV	12 Feb 74 V	13 Mar 74 VI	29 Mar 74 VII	18 Apr 74 VIII	29 May 74 IX
Station	TB-B1	.140 (.130-.150) 44		---	---	---	---	---	---	---	---	---
	TB-B2		.207 (.184-.230) 23	---	---	---	---	---	---	---	---	---
	TB			.165 (.150-.180) 26	.195 (.178-.212) 15	.283 (.252-.314) 17	.333 (.308-.358) 27	.414 (.337-.492) 15	.313 (.291-.336) 27	---	---	.256 (.219-.292) 10
	NO			---	---	---	---	.305 (.267-.342) 19	---	---	---	---
	ST			.284 (.246-.323) 22	.298 (.246-.351) 15	.373 (.314-.433) 18	.490 (.443-.567) 23	---	---	---	---	---
	SO			---	---	---	---	.277 (.233-.320) 18	.296 (.155-.437) 4	---	---	---
	T			.299 (.266-.322) 26	.294 (.253-.335) 27	.433 (.386-.479) 26	.453 (.414-.493) 27	.463 (.319-.607) 5	---	---	---	---
	TO			---	---	---	---	.315 (.283-.347) 23	.282 (.220-.344) 2	---	---	---
	D			.262 (.233-.291) 26	.298 (.267-.330) 27	.313 (.280-.345) 27	.386 (.342-.430) 22	.438 (.411-.466) 22	---	---	---	---
	MO			---	---	---	---	---	.402 (.301-.502) 14	.445 (.388-.503) 27	.504 (.439-.568) 4	---
	SP			.219 (.197-.242) 27	.277 (.243-.312) 24	.428 (.387-.469) 26	.512 (.444-.581) 22	.496 (.456-.536) 13	---	---	---	---